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LAURENTIAN LIMESTONES

OF

NORTH AMERICA.

By T. STERRY HUNT, LL.D., F.R.S.

REPORT OF THE REGENTS OF THE UNIVERSITY

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APPENDIX E.

ON THE

LAURENTIAN LIMESTONES

OF

NORTH AMERICA

BY

T. STERRY HUNT, LL.D., F.R.S.

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ON THE MINERALOGY OF THE LAURENTIAN LIMESTONES OF NORTH AMERICA.

By T. Sterry Hunt, LL. D., F. R. S., of the Geological Survey of Canada.

Introduction.

In a general report of the Geological Survey published in 1863, under the title of the *Geology of Canada*, the ancient gneissic system of the Laurentides of Canada and the Adirondacks of New York, is described under the name of the Laurentian system. Farther researches have shown that under this title were included two distinct and unconformable groups of rocks, which have since been distinguished as the Lower Laurentian and the Upper Laurentian, or Labrador series. The first and most ancient of these, to which it will be well for the future to restrict the name of Laurentian, corresponds to the primitive gneiss of Scandinavia and of the west of Scotland. This opinion was put forward by the author in 1855, and has since been confirmed by Sir R. I. Murchison, for Scotland. More recently, Messrs Gümbel and Hochstetter, after a lengthened study of the older gneiss of Bavaria and Bohemia, have declared it to be identical with the Laurentian of North America, a conclusion sustained by the discovery by Gümbel of the fossil remains of the rhizopod *Eozoon Canadense*, in the limestone of the Bavarian gneiss.

The lower or true Laurentian consists in great part of orthoclase gneiss, sometimes granitoid, with quartzites, occasionally becoming conglomerates ; hornblendic and micaceous schists, pyroxenites, serpentines and limestones, sometimes magnesian. These limestones, generally very crystalline, are seen on the Ottawa, in the counties of Argenteuil and Grenville, to form three distinct formations, having each a thickness of from 1,000 to 1,500 feet, separated, underlaid and overlaid by still greater masses of gneiss and quartzite. The measured thickness of this series on the Ottawa is more than 20,000 feet, which is probably far from representing its total volume, while in Bohemia it is supposed to equal not less than 90,000 feet. In the county of Hastings, in the province of Ontario, not less than 21,000 feet of strata, consisting of crystalline schists, limestones and diorites, are found resting conformably upon Laurentian gneiss.* It appears certain, however, that this series, which differs both in the succession and the lithological character of its strata from the sections in the Ottawa valley, belongs to the Lower Laurentian, of which it would appear to constitute a member higher in the system than any observed in New York or in the province of Quebec, so that the whole known thickness of the Lower Laurentian in Canada would surpass 40,000 feet. The *Eozoon Canadense* is met with in several localities, both in the lower and higher members of the Lower Laurentian.

The Labrador (or Upper Laurentian) occurs in detached areas, resting unconformably upon the true Laurentian system. Some of these areas are many miles in breadth, and they occur at intervals in Canada from the shores of Lake Huron to the coast of Labrador. The Labrador series contains strata of orthoclase gneiss, quartzites, and crystalline limestones; but its predominant element is an anortholite—a rock composed essentially of a feldspar of the anorthic or triclinic system, generally with a small admixture of pyroxene or hypersthene. This anortholite is sometimes gneissoid, and even fine-grained; but is more often granitoid, and occasionally presents large cleavable masses of opalescent feldspar, generally labradorite or andesine. The thickness of this Labrador series cannot be less than 10,000 feet, and is perhaps much more. The true Laurentian offers nothing similar to these anortholites, which seem to be identical, both lithologically and geognostically, with the norites of Norway. They are the hypersthenites of the Hebrides, described by McCulloch, and subsequently recognized by Emmons under the name of hypersthene rock in the Adirondacks, of which, according to him, they form some of the highest summits.

To these two great series of ancient rocks must be added a third—the Huronian, which attains on Lake Huron a thickness of not less than 18,000 feet, where it lies between the Laurentian and Silurian systems, conformable with neither. It is believed to be newer than the Labrador series, though the two have never yet been seen in contact. The recent observations of Prof. Hall, have shown that the Huronian system is found interposed between the Silurian and the Laurentian to the west of the Mississippi, while it appears to have been very recently identified both in Newfoundland and in New Brunswick. Of these three great series, Sir William Logan remarks that their united thickness "may possibly far surpass that of all the succeeding rocks from the base of the Potsdam series to the present time. We are thus carried back to a period so far remote, that the appearance of the so-called primordial fauna may by some be considered a comparatively modern event. We find, however, that even during the Laurentian period, the same chemical and mechanical processes which have ever since been at work disintegrating and reconstructing the earth's crust, were in operation, as now. In the conglomerates of the Huronian series, there are enclosed boulders derived from the Laurentian, that seem to show that the parent rock was altered to its present crystalline condition before the deposit of the newer formation, while interstratified with the Laurentian limestones, there are beds of conglomerate, the pebbles of which are themselves rolled fragments of a still older laminated sand-rock; and the formation of these beds leads us still further into the past." (*Quar. Jour. Geol. Soc.*, February, 1865.)

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* See postscript on page 98.

The area occupied by the Laurentian rocks in Canada, is about 200,000 square miles, of which about 1,500 square miles have been accurately studied and mapped in the valley of the Ottawa, in the province of Quebec, and a still smaller area in the county of Hastings, Ontario. The Laurentian area of the Adirondacks, in northern New York, comprises about 10,000 square miles, but has never yet been stratigraphically studied, although much attention has been paid to the mineralogy of the limestones of the series, which present many characters both of scientific and of economic interest. The following pages are extracted from the Report of the Geological Survey of Canada for 1863–66 (pages 182–223), published at Ottawa, and here reprinted with some few additions, which are distinguished by being enclosed in brackets :

The evidence afforded by the careful stratigraphical study of these Laurentian limestones, and their associated rocks in the valley of the Ottawa, left, as we have seen, no doubt of their sedimentary nature and origin. Similar limestones in the Highlands of New York and New Jersey were long since recognized by Rogers, by Mather, and by other American geologists, as in like manner altered stratified rocks, which were by some regarded as of Silurian age, and by others of greater antiquity. The observations made by Sir William Logan and Prof. James Hall, in 1864 (*Amer. Jour. Science* [2], xxxix, 97), in the Highlands of the Hudson, however, leave no doubt that these limestones, and their accompanying gneissoid strata, belong to the Laurentian system.

The study by the late Dr. Emmons of the similar series of rocks, constituting the mountain region of the Adirondacks in northern New York, and continuous with the great Laurentian area of Canada, led him, however, to regard the limestones of the series as of igneous origin, and in fact as intrusive rocks. (See his Report on the Geology of the First District of New York, published in 1842, pages 37–59.) This view, although in contradiction with the conclusions of other geologists who have examined these Laurentian limestones in Canada and the United States, was not so singular as might at first sight appear. Mather, in his Report on Second District of New York (page 485), while maintaining the sedimentary and metamorphic nature of the crystalline limestones of the Highlands, asserted that there were examples in Washington county fully sustaining Emmons' view that such limestones sometimes occur as eruptive rocks.

Many of the first geologists of other countries have also maintained the igneous origin of certain crystalline limestones. Thus, in 1863, we find Von Leonhard asserting that limestones have sometimes come from the interior of the earth in a liquid state, like other igneous rocks. A similar view was at that time maintained by Guidini with regard to the dolomites of Spezzia in northern Italy, and by Rozet for similar rocks at Oran in Algeria, and for the crystalline limestones of the Vosges, which, like those of the Laurentian series, occur in gneiss, and are often mingled with serpentine. (*Bull. Soc. Geol. de France*, iii, pages 215 and 235.) These observers, like Dr. Emmons, urged in support of their view, among other reasons more or less fallacious, the undoubted fact that such limestones, in some cases, apparently form dykes or veins, which, like those of granite and greenstone, traverse gneissic or quartzose strata.

It has been pointed out in the Geology of Canada (pages 28 and 643), that, in the case of the Laurentian limestones, there is abundant evidence that they were at one time in such a plastic condition that external forces were able, not only to contort great masses of limestone, and to break and fold in a remarkable manner certain interstratified quartzose layers, but to force the softened limestone into fissures in the adjacent silicious strata. Examples of the latter phenomenon are, however, comparatively rare, and the limestone veins upon which Mr. Emmons, and probably other observers, have founded their view of the igneous origin of crystalline limestone, remain to be described, after a brief account of the limestones and their immediately associated strata. It should here be mentioned that Bischof considers the great dykes of granular limestone, which, near Auerbach in the Bergstrasse, are met with traversing gneiss, to be deposits from water, filling up fissures; in fact, veritable veinstones. (*Chem. Geol.*, *English Ed.*, iii, pp. 148–150.) See also the note on page 47 for a description of a similar calcareous vein.

The Laurentian limestones of North America, and other crystalline limestones in different regions, some of which belong to other geological periods, often abound, as is well known, in foreign minerals. These occur disseminated through the mass of the rock, of which they serve, in many cases, to mark the lines of stratification. While some beds consist of nearly pure carbonate of lime, others will be found to be characterized by an admixture of grains or crystals of chondrodite, pyroxene, serpentine, mica, feldspar, quartz, graphite, or other minerals, either alone or variously associated, and sometimes in such quantities as to make up a large proportion of the rock.

Recent investigations have shown that in some cases the dissemination of certain of these minerals through the crystalline limestones is connected with organic forms. The observations of Dr. Dawson and myself on the *Eozoon Canadense* showed that certain silicates, namely, serpentine, pyroxene and loganite, had been deposited in the cells and chambers left vacant by the disappearance of the animal matter from the calcareous skeleton of that foraminiferous organism, so that when this calcareous portion is removed by an acid there remains a coherent mass, which is a cast of the soft parts of the animal, in which not only the chambers and connecting canals, but the minute tubuli and pores are represented by solid mineral silicates. It was shown that this process must have taken place during the life of the animal or immediately after its death, and must have depended upon the deposition of these silicates from the waters of the ocean.

The train of investigation thus opened up has been pursued by Dr. Gümbel, Director of the Geological Survey of Bavaria, who, in a recent remarkable memoir presented to the Royal Society of that country, has detailed his results.

Having first detected a fossil identical with the Canadian Eozoon (together with several other curious microscopic organic forms not yet observed in Canada), replaced by serpentine in a crystalline limestone from the primitive gneiss of Bavaria, which he identifies with the Laurentian system of this country, he next discovered a related organism, to which he has given the name of *Eozoon Bavaricum.* This occurs in a crystalline limestone belonging to a series of rocks more recent than the Laurentian, but older than the primordial zone of the Lower Silurian, and designated by him the Hercynian clay-slate series, which he conceives may represent the Cambrian system of Great Britain, and perhaps correspond to the Huronian series of Canada and the United States. The cast of the soft parts of this new fossil is, according to Gümbel, in part of serpentine and in part of hornblende.

His attention was next directed to the green hornblende (pargasite), which occurs in the crystalline limestone of Pargas, in Finland, and remains, when the carbonate of lime is dissolved, as a coherent mass, closely resembling that left by the irregular or acervuline varieties of Eozoon. These grains are described as somewhat cylindrical in form, with rounded and pitted surfaces, presenting re-entering angles, and resembling, on a small scale, the tubers of some plants. Though thus destitute of external crystalline form, they have a perfect cleavage, and are entirely crystalline within. These small tuberculated grains are joined together by short cylinders, and are occasionally traversed by cylindrical openings; besides which, there are implanted upon them small cylinders, often branched, and resembling exactly in size and arrangement the casts of the tubuli of Eozoon, in which, or in some related organic structure, he conceives the pargasite to have been moulded. A white mineral, probably scapolite, was found to constitute some tubercles associated with the pargasite, and the two mineral species were in some cases united in the same rounded grain.

Similar observations were made by him upon specimens of coccolite, or green pyroxene, occuring in rounded and wrinkled grains in a Laurentian limestone from New York. These, according to Gümbel, present the same connecting cylinders and branching stems as the pargasite, and are by him supposed to have been moulded in the same manner. The continuity of the casts of the tubuli appears to have been, for the most part, destroyed by the subsequent crystallization of the carbonate of lime, in more compact portions of which they are, however, occasionally preserved. The fine residue from the solution of the lime in acids gave other minute organic forms, similar to those noticed by him in the Eozoon limestone of Bavaria. Very beautiful evidences of the same organic structure, consisting of the casts of tubuli and their ramifications, were also observed by Gümbel in a finely crystalline limestone, enclosing granules of chondrodite, hornblende, and garnet, from Boden, in Saxony. Other specimens of limestone, both with and without serpentine and chondrodite, were examined without exhibiting any traces of these peculiar forms, and these negative results are justly deemed by Gümbel as going to prove that their structure is really, like that of Eozoon, the result of the intervention of organic forms. In this connection, an observation made by Sir William Logan with regard to the Eozoon rock of Canada is very important, namely: that the granular mixture of carbonate of lime and serpentine which accompanies the perfect forms of Eozoon, consists of broken and comminuted portions of the fossil, still exhibiting minute structure, and having a stratified arrangement. Besides the minerals mentioned above as having been observed as the replacing substance of the Eozoon in Canada, namely, serpentine, pyroxene, and loganite, Gümbel adds chondrodite, hornblende, scapolite (?), and probably, also pyrallolite, quartz, and iolite or dichroite.

Accompanying the crystalline limestones of the Laurentian system in Canada, are often found strata made up of foreign minerals to the entire exclusion of carbonate of lime, by an admixture of which, however, they gradually pass into the adjacent limestones. These strata generally consist of pyroxene, sometimes nearly pure, and at other times mingled with mica, or with quartz and orthoclase, often associated with hornblende, epidote, magnetite, sphene and graphite. These beds, which may for the most part be described as pyroxenites, from the prevailing mineral, and which have been briefly noticed in the Geology of Canada, page

475, are generally granitoid or gneissoid in structure. They are sometimes fine grained, and at other times made up of crystalline elements from two-tenths to five-tenths of an inch in diameter. They occasionally assume a great thickness, and are then often interstratified with beds of granitoid orthoclase gneiss, into which the quartzo-felspathic pyroxenites pass by a gradual disappearance of the pyroxene. These peculiar strata, which contain at the same time the minerals of the associated gneiss and of the limestones, may thus be looked upon as beds of passage between the two rocks. Their mineral species and varieties, so far as my observations go, are identical with those of the limestones themselves. It should be remembered that, besides the minerals already mentioned as predominating in these strata, other species characteristic of the limestones, such as serpentine and magnetite, sometimes make up by themselves great beds in these intermediate or transition strata, which, from their mineralogical relations, may all be looked upon as related to the accompanying limestones. In some districts, however, hornblende predominates over the pyroxene, and gives rise to beds of pure hornblende rock, or amphibolite, sometimes schistose, and to compound rocks, such as diorite and hornblendic gneiss, so that each group of limestones, with its attendant pyroxenites, amphibolites, serpentines, magnetites, etc., may be considered as characterizing an epoch in the geological period to which it belongs.

Each one of the three great limestone formations which have been recognized in the Laurentian system on the Ottawa, appears to be associated with these related rocks, which are, however, in some parts, developed to a great extent, and in others are comparatively unimportant in volume. These limestone groups, as we may hereafter designate the limestones with their attendant rocks, appear to be the parts of the system to which the principal economic minerals belong. The ores of iron, copper, nickel and cobalt, the apatite, mica and plumbago, as well as the serpentines and the marbles of the great Lower Laurentian series, belong, so far as yet known, to the limestone groups.

The Labrador or Upper Laurentian series includes one, and perhaps more limestone bands, which, so far as ascertained, present the same mineralogical accompaniments as the limestone formations of the Lower Laurentian.

MINERAL VEINS.

We may now consider the mineral veins which traverse the

Laurentian rocks, and have chiefly been studied in connection with these limestone groups, where they present the most varied and important mineralogical characters. These veins have been briefly described in the *Geology of Canada*, pages 35–37, where three classes of them are distinguished as follows :

1. Veins filled chiefly with calcareous spar, sometimes with sulphate of barytes or fluor-spar, and carrying sulphuret of lead, and more rarely, sulphurets of zinc, iron and copper. Numbers of these metalliferous veins have been described in speaking of the various metals in chapter xxi of the Geology, and others are noticed by Mr. Macfarlane in his report on the county of Hastings (*Geol. Survey of Canada*, 1866). These veins are much newer than the Laurentian rocks, since they traverse in Ramsay, Ontario, the strata of the Calciferous formation (*Geol. Can.*, page 636). Similar veins are also met with in Lewis county, New York, intersecting the limestones of the Trenton group, and sometimes containing fluor-spar. The vein in the Laurentian limestone on Muscalunge lake, St. Lawrence county, New York, which contains besides calcite, the huge crystals of fluor-spar so well known to mineralogists, may probably belong to the same class as the lead-bearing veins just mentioned.*

2. The veins of the second class are filled with quartz and orthoclase feldspar, which is sometimes replaced by, or associated with albite. These veins occasionally include crystals of black or white mica (muscovite), large crystals of black hornblende, and not unfrequently black tourmaline, red garnet and zircon. One of this class, cutting the Laurentian gneiss in Greenfield, near Saratoga, New York, contains, in addition to garnet and tourmaline, the rare species chrysoberyl ; and the granitic vein holding crystals of beryl, observed by Dr. Bigsby in the gneiss of Rainy

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* In this connection may be mentioned a vein of this class, remarkable for its size, which occurs at Spencerville, near Prescott, Ontario, and has attracted some attention in the neighborhood. It is on the east half of lot twenty-eight, in the sixth range of Edwardsburg, and cuts the horizontal strata of the Calciferous formation, which is here bare of soil, and holds nodules of chert. The vein, which runs E. N. E., has been traced on the surface for a distance of about one hundred rods, and at the place where it has been opened is not less than eighteen feet wide, and vertical in its attitude. A pit had been sunk on the vein at the time of my visit, in August, 1864, to depth of twenty feet. The veinstone was pure white crystalline carbonate of lime, without any traces of banded structure; and in detached blocks the greater part of it could not be distinguished from many saccharoidal limestones. Occasionally, however, masses of a coarsely cleavable and lilac-colored calcite were met with. The only foreign minerals in this vein were small and rare grains of copper pyrites, and more frequently, iron pyrites in thin testaceous crusts, also very sparsely distributed. Another, and a smaller vein, was observed nearly parallel to this, filled with a similar carbonate of lime, but without any visible metallic impregnation.

Lake, possibly belongs to Laurentian rocks (*Geol. Can.*, page 492). These veins, from their constituent minerals, are generally described as granitic, but are not to be confounded with injected granite dykes, since they are doubtless true veins, like those of the first class, filled by the gradual deposition of matters from aqueous solutions. These granitic veins, unlike those of the preceding class, have not been observed to intersect the Silurian rocks, and are probably of greater antiquity than they. As will hereafter be shown, they cannot be distinguished from the veins of the third class, into which they pass by insensible degrees.

3. In the third class were included, in the Geology of Canada, those veins which appear to be more nearly related to the limestone groups, with which they are generally associated, and with the characteristic minerals of which they are filled. These veins are extremely numerous, and exhibit, within certain limits, remarkable variations in mineralogical characters. The most important elements of these veins are calcite, quartz, orthoclase, phlogopite, pyroxene, apatite and graphite, of which some one or more will be found to prevail; but they may contain, besides, numerous other species, including nearly every one to be met with in the limestones, and in their accompanying pyroxenic and gneissic rocks. Veins of the present class are found traversing all these strata; they are most frequently vertical in attitude, and generally cut the beds at right angles, though to this many exceptions may be cited. They exhibit, within certain limits, great variations in their mineralogical characters, not only in different veins, but in different parts of the same vein. Thus, in some cases, pyroxene is the predominant mineral, and other species are present only in small quantities. At other times, orthoclase, apatite, or magnesian mica makes up the great mass of the vein, and in other cases, calcareous spar. It is the veins of this latter mineral which have doubtless been, by Emmons and other observers, described as intrusive veins of crystalline limestone. Having generally a solidly crystalline lamellar structure, very unlike the more or less cavernous calcareous veinstones of the first class, and sometimes holding only sparsely disseminated crystals of one or more of the minerals which are common to the stratified limestones, such as pyroxene, mica, or apatite, the observer will often find it difficult to determine whether a detached mass, or an imperfectly displayed out-crop of crystalline limestone, belongs to a bed or a vein. When, however, it is possible to make a thorough exami-

nation of the locality, it will be found in the latter case that the deposit occurs in a fissure cutting the stratification, and as well-defined walls.

A banded arrangement of the mineral contents is often very well marked. Thus, while the walls may be coated with crystalline hornblende, or with phlogopite, the body of the vein will be filled with apatite, in the midst of which may be found a mass of crystalline orthoclase, or of loganite, occupying the centre of the vein. In other instances, portions of the vein will be occupied by crystals of apatite, pyroxene, or phlogopite, imbedded in calcareous spar, which, in some other part of the breadth of the vein, or in its prolongation, will so far predominate as to give to the mass the aspect of a coarsely crystalline lamellar limestone. Most of the well crystallized minerals described by observers, both on this continent and in Europe, as occuring in crystalline limestones, appear to be derived from calcareous veins like those just described.

In like manner I have described localities of crystallized apatite as occuring in beds of limestones in Burgess, Ontario, where a subsequent examination (while confirming the existence of this mineral in the limestone beds of that region) has shown, nevertheless, that the workable deposits are with few, if any, exceptions confined to the veinstones.

From a lithological point of view, there cannot be any objection to extending the name of limestone to these calcareous veinstones; but geologically, it becomes important to discriminate between them and those great masses of limestone which are sedimentary deposits.

That these deposits of mineral matter, occupying fissures in the stratified rocks, are not intrusive veins or dykes, but have been formed by gradual deposition or accretion, is shown by the banded arrangement parallel to the walls, just noticed. Further evidence of this origin is seen in the manner in which the various minerals surround or incrust each other. Thus, small prisms of apatite are enclosed in large crystals of phlogopite, in spinel, and even in massive apatite; crystals or crystalline masses of calcite are imbedded in apatite and in quartz, and well-defined crystals of hornblende (pargasite) occur imbedded in others of pyroxene. In another example, small crystals of hornblende are implanted on a large crystal of pyroxene, and both of these are, in their turn, incrusted by small prisms of epidote. This latter crystal was evidently from a drusy cavity, such as those often met with, representing unfilled spaces in the midst of the veins, and lined with large and well-defined prisms of apatite or of pyroxene.

While these associations evidently show a successive deposition of the various mineral species, another phenomenon, sometimes observed in vein-crystals, is presented by a prism of yellow idocrase from a veinstone of orthoclase and pyroxene in Grenville, Quebec. One extremity of the prism, which is about half an inch in diameter, is imbedded in the matrix of the two minerals just named, while the other, being broken across, shows that the idocrase forms but a thin incrusting shell, and is filled with a confused crystalline aggregrate of orthoclase, holding a small prism of zircon. This would show that a skeleton-crystal, such as is sometimes seen in crystallizing solutions, had at first formed, and was subseqnently filled up with the other minerals. Similar cases are well known to mineralogists; thus the crystals of zircon from Laurentian veins in St. Lawrence county, New York, are sometimes filled with calcareous spar; and a granitic vein at Haddam, Connecticut, has afforded prisms of beryl filled with a mixture of orthoclase and quartz holding minute crystals of garnet and of tourmaline. A strong confirmation of the view that these minerals have been deposited in their veins from solution, is afforded by certain phenomena not hitherto explained, which were, I believe, first noticed by the late Dr. Emmons. He observed that crystals of quartz imbedded in crystalline limestone, in Rossie, New York, have their angles so much rounded that the prismatic form is almost or entirely effaced, the surfaces being smooth and shining. This appearance, although not constant, is observed in many localities, and is not confined to quartz alone—crystals of apatite and of carbonate of lime sometimes exhibiting the same peculiarity. At the same time as remarked by Dr. Emmons, the feldspar, scapolite, pyroxene, zircon and sphene of these limestones present perfect forms, the crystals of orthoclase, even in contact with the rounded crystals of quartz, retaining their sharpness of outline. Dr. Emmons considered the rounded angles of these cyrstals to be due to a partial fusion, though at the same time he did not overlook the fact that the quartz, apatite and calcite were less fusible than those species which, under similar circumstances, retained their crystalline forms intact (*Geology of the First District of New York*, pages 57, 58).

These observations have since been abundantly confirmed in

Canada. The crystals of apatite in Elmsley and Burgess, Ontario, rarely present sharp or well-defined forms; but whether lining drusy cavities, or imbedded in the calcareous veinstone, present rounded or sub-cylindrical crystalline masses, while the pyroxene and sphene, which often accompany them, preserve the sharpness of their angles. The hypothesis which would explain by igneous fusion this rounding of the angles, is evidently untenable, first, because the more fusible species show no signs of such action, and, second, because the carbonate of lime, which encloses and even penetrates the rounded quartz crystals, is not in any way affected at the surfaces of contact as it would have been by fused or half-fused quartz. This rounding of the angles of certain crystals appears to me to be nothing more than a result of the solvent action of the heated watery solutions, from which the minerals of these veins have been successively deposited, the crytals previously formed being partially redissolved as a result of some change in the temperature, or in the chemical constitution of the solution. Heated solutions of alkaline silicates, as shown by Daubrée, are without action on feldspars, as might be expected from the fact, observed by him, of the production of crystals of feldspar and of pyroxene in the midst of such solutions. These liquids would, however doubtless attack and dissolve phosphate of lime, which is, in like manner, decomposed by solutions of alkaline carbonates, and these latter at elevated temperatures attack and dissolve crystallized quartz.

The regularity, and the frequently large dimensions of the crystals, not less than their modes of association, and the other phenomena just mentioned, serve to distinguish the minerals of these veinstones from the same species which are found disseminated in the limestone beds. In the latter case they sometimes occur in small distinct crystals, but more generally in rounded irregular grains, which present a marked contrast to the same minerals occuring in the veins. This rounded form of the minerals in the beds of limestone, is to be carefully distinguished from the rounding of the crystals in the veins just described, although the two phenomena have hitherto been confounded by those who have written upon the subject. In the latter case the rounding is by no means constant, and is confined to a few species, while in the limestone beds it will be found that a rounded form characterizes alike apatite and quartz, and such silicates as pyroxene, hornblende, serpentine and chondrodite. The rounded shapes assumed by these minerals in limestone, and especially by the silicates just mentioned, have been noticed by Naumann and Delesse, among others; and the latter observer supposed that this condition might be due to a repulsive action between the particles of the silicates and the surrounding calcareous matter when both were in a plastic state under the influence of water and heat. The observations of Dawson and myself, and the latter ones of Gümbel, however, as detailed on pages 43 and 44, demonstrate that this rounded form, in many cases, at least, is due to no such subsequent action, but has been given by the calcareous organic structure, in whose chambers these silicates were originally deposited. It would, however, be premature to say that this explanation is of universal application, but it may be affirmed in general terms, that certain external forces have, in the limestone beds, prevented the free development which these mineral species naturally assume while in the veinstones. On the contrary, the rounding of the angles of certain crystals, to the exclusion of others, is due to a partial dissolution of the previously formed crystals.

As already remarked, it is impossible to draw any definite line between the veins just described and those already mentioned as placed in the preceding class, and generally designated as granitic veins. Most of their characteristic minerals are common to the two classes, and it is easy to trace a gradual change from the typical granitic veins, to those in which carbonate of lime is the predominant mineral, and which are to the crystalline limestones what the former are to gneiss and mica-schist. In both cases I conceive that they derive their mineral contents from the adjacent strata, whose fissures they fill, and are entitled to the name of segregated veins. In both cases, also, it must be borne in mind that other vacant spaces in the strata, whether resulting from contraction, solution, or other causes, may present conditions for deposition similar to those of fissures, and may thus give rise to drusy cavities, or to detached masses of crystalline minerals identical to those of the veinstones. This view of the origin of granitic veins from solution, and their distinction from intrusive granites, has been insisted upon by me in the *Geology of Canada*, pages 477, 644, and since, with more details, in my Contributions to Lithology in the *American Journal of Sceince* [2], xxxvii, 252.

To resume, then, it may be said that besides the fissures filled with igneous injected granite, forming what may be distinguished as *granitic dykes*, there are other fissures which have, by a slow deposition from solutions, been filled with the constituent minerals of granite, constituting true *granitic veinstones*, which, unlike the granitic dykes, are often rich in foreign minerals. These aggregates pass by gradations into the pyroxenic and calcareous veinstones already noticed. It is from not knowing this distinction that Durocher, Fournet and others have perplexed themselves with strange hypotheses in attempting to explain the phenomena presented by the associations and juxtapositions of mineral species in granitic veinstones, which they imagined to have been formed, like granitic dykes, by the consolidation of a fused or pasty mass, instead of being the result of a slow deposition from solution. For convenience of definition, I have elsewhere distinguished these veinstones by the title of *endogenous* rocks, as describing the conditions of their formation. The intrusive dykes, on the other hand, I have called *exotic*, and the sedimentary strata, *indigenous* rocks.

As to the conditions under which these various minerals have been crystallized, the beautiful researches of Sorby furnish us considerable light. The limestones, from Somma, near Naples, afford, in a finely crystallized state, the greater number of the mineral species met with in the Laurentian limestones of North America, and the crystals of hornblende, idocrase and orthoclase from that locality contain small cavities, often of microscopic dimensions, partially filled with water, holding in solution alkaline chlorides, sulphates and carbonates. As these cavities were filled with liquid during the formation of the crystal, the subsequent cooling has produced a partial vacuum ; this is again filled on heating the crystal to the temperature at which it was formed, which in this way may be approximately determined. Mr. Sorby found, by this method, that the hornblende, idocrase and feldspar from the limestones of Somma must have been crystallized at from 360° to 380° Centigrade, a temperature equal to that of low redness. The crystals from the granitic veins of Cornwall, including quartz, mica, orthoclase and oxyd of tin, all of which contain cavities holding watery solutions, have shown, in like manner, to Mr. Sorby, that these minerals must have been deposited at temperatures approaching those deduced for the minerals from the crystalline limestones of Somma, or from 200° to 340° Centigrade (from 392° to 644° Fahrenheit) (*Quar. Jour. Geol. Soc.*, London, xiv, 453). He thence concludes that these minerals have crystallized at temperatures in some cases equal to that of low redness, under a pressure equal to that of several thousand feet of rock, and in the presence of water holding in solution a large amount of alkaline salts, which can in some instances be detected in the liquid from these cavities.

These conclusions are supported by the experiments of Daubrée, who succeeded in forming crystallized pyroxene, feldspar and quartz, in the presence of alkaline solutions at a low red heat. De Senarmont also obtained crystallized fluor-spar, sulphate of barytes and quartz, in the presence of water, at temperatures between 200° and 300° Centigrade. The deposits from the thermal waters of Plombières, however, show that some hydrous silicates, like apophyllite, harmotome and chabazite, may be crystallized at temperatures below that of boiling water, and there are reasons for believing that quartz may also be crystallized at low temperatures. Thus, while the observations of Sorby show the temperatures at which certain minerals have been crystallized, it does not necessarily follow that some of these crystals may not be generated at lower degrees of heat, which, for the minerals found in nature, must, in each case, be determined by experiments like those of Mr. Sorby.

It will be readily understood that the conclusions as to the conditions of temperature under which certain minerals have been crystallized, apply with equal force to those freely deposited in fissures or cavities of the sedimentary rocks, and those which may have cyrstallized in the midst of the deeply buried sediments themselves; since these must have been permeated with the same solutions which circulated in the fissures, and which, in fact, derived from the beds their dissolved mineral matters. The solvent power of waters holding alkaline carbonates and silicates, and heated to 300° or 360° Centigrade, is probably very great. The questions of the generation of many of these silicates, and of the original composition of the sedimentary rocks, will be discussed further on.

Those who have written on crystalline limestones, and on their mineralogy, have, for the most part, neglected the distinction between the rock and its veins; thus Delesse in his elaborate memoir on the minerals of crystalline limestones, does not even allude to it. Incidentally, however, several observers have noticed the occurrence of various crystallized minerals in veins among the Laurentian limestones of New York and New Jersey. First among these may be mentioned Prof. Charles Upham Shepard, who, in

1832, published a description of the minerals of Orange county, New York (*Amer. Jour. Science* [1], xxi, 321). Prof. H. D. Rogers also, in his Final Report on the Geology of New Jersey, notices the occurrence of aggregates of carbonate of lime, with feldspar, hornblende, pyroxene, sphene, spinel, etc., forming dykes or veins in the crystalline limestone of that region; and shows, moreover, that the franklinite and red zinc ore, with their associated minerals, occur in calcareous veins. Finally, Mr. W. P. Blake, in describing a locality of the first mentioned group of minerals in Vernon, New Jersey, declares it to have the characters of a segregated vein (*Amer. Jour. Science* [2], xiii, 116). Despite these observations, however, Emmons and Mather did not regard the distinction which evidently exists between the bedded limestones and the veins, many of which, from a predominance of carbonate of lime in their composition, became confounded in their eyes with the limestones themselves, leading both of these observers, as we have already seen, to admit the existence of eruptive limestones; while Emmons even concluded that all the limestones of the northern Laurentian district of New York were non-stratified, and of eruptive origin. A careful geognostic study will, however, we think, suffice to show that by far the greater part of the calcareous rocks in the Laurentian system of North America are stratified, and that the so-called eruptive limestones are really calcareous veinstones, or endogenous rocks, generally including foreign minerals, such as pyroxene, scapolite, orthoclase, quartz, etc. These, in other veins, predominate to the exclusion of carbonate of lime, and then present aggregates approaching in composition to the granitic veinstones, into which they pass by the exclusion of calcareous and magnesian minerals, such as calcite, apatite, pyroxene, magnesian mica, scapolite, etc. These species serve to distinguish the veins of the limestone groups from the proper granitic veinstones, in which latter, orthoclase, albite, quartz and muscovite are the characteristic minerals.

The so-called Primitive Gneiss formation of Scandinavia has long been regarded by the Geological Survey as belonging to the Laurentian system (*Esquisse Géologique du Canada*, p. 17; *Geology of Canada*, p. 586), and is associated with crystalline limestones, which have afforded most of the minerals that are to be met with in the Laurentian limestones of North America, together with many additional species. Such of these minerals as are common to the two regions, offer close resemblances, not only in their characters and associations, but also in the mode of their occurrence. These resemblances were in fact noticed so long ago as 1827 by Dr. William Meade (*Amer. Jour. Science* [1], xii, 303), who called attention to the great similarity between many Scandinavian minerals, particularly from the vicinity of Arendal, and those found in Orange county, New York, and in Sussex county, New Jersey. He instanced, among others, the species pyroxene, chondrodite, scapolite, garnet, sphene and ilmenite. Daubrée, who in 1843 published an instructive account of his examination of the metalliferous deposits of Norway and Sweden, furnishes some interesting details of the minerals associated with the beds of magnetic iron ore in the vicinity of Arendal (*Ann. des Mines* [4]. iv, pp. 199, 282). The ore is here found, sometimes in gneiss, and at other times in a gneissoid rock, consisting of various admixtures of pyroxene, hornblende, garnet, epidote and mica, the whole associated with crystalline limestones. These strata are cut by numerous well defined but irregular veins, which are described by Daubrée as granitic or syenitic in character, and have yielded the following minerals: Orthoclase, scapolite, quartz, apatite, lamellar carbonate of lime, hornblende, black mica in large plates, garnet, epidote, allanite, gadolinite, axinite, zircon, sphene, spinel, specular iron, and more rarely, beryl and leucite. Serpentine, chondrodite, lievrite and corundum are also enumerated among the minerals of the district, though not especially mentioned by Daubrée as occurring in the veins. In addition to the species already mentioned, these veins contain datholite and apophyllite, with analcime and various other zeolites, which are, however, possibly of later origin than the other minerals. These veins sometimes include irregular fragments of the wall-rock, and present cavities lined with crystals, showing, not less clearly than the veins which we have mentioned in the Laurentian rocks of Canada, that they have been formed by the progressive filling up of fissures in the strata.

In some instances, these veinstones, by the absence of calcareous and magnesian minerals, become granite-like aggregates of orthoclase and quartz. Daubrée, however, having reference to their structure, calls all of these veins granitic, though they sometimes contain lamellar carbonate of lime. He agrees with Scheerer in supposing them to have been filled by segregation or secretion from the surrounding strata, while Durocher, on the contrary, rejected this view, and supposed them to have been filled by injection.

These veins are seldom of great extent, and near Stockholm, where they are very abundant, rarely exceed 300 feet in length.

At the iron mines in the island of Utoë, where the ore is a mixture of magnetic and specular oxyds, occurring in beds, with hornblendic rocks passing into gneiss, or with crystalline limestone holding hornblende and mica, granitoid veinstones, like those of Arendal, are met with, holding orthoclase and quartz, with tourmaline and oxyd of tin, together with the rare minerals, petalite, spodumene and lepidolite, which occupy the central portion of the veins. This association is the more worthy of notice, as the only other known locality of the rare mineral petalite (if we except the castor of Elba) is in the crystalline limestone of Bolton, Massachusetts, where it occurs with scapolite, hornblende, pyroxene, chrysolite, spinel, apatite and sphene—the characteristic minerals of similar limestones in Canada, New York and Scandinavia.

The occurrence of oxyd of tin in the above associations is not without interest in relation to the economic mineralogy of the Laurentian system, to which the rocks of Utoë probably belong; and it is well to recall, in this connection, the existence of tin ore in rocks, probably of the same age, at Pitkaranta, on Lake Ladoga, in Finland. A rock consisting of greenish lamellar hornblende, with garnet, epidote and pyroxene, is there interstratified with mica-slates, sometimes graphitic, and with a granitic gneiss, the series being cut by granite-like veins. In certain beds of the hornblendic rock, magnetic iron is disseminated to such an extent that the mass becomes an iron ore. This is occasionally associated with oxyd of tin, which in some parts predominates, so that the ore is mined for this metal. Other hornblendic beds in the series are rich in copper pyrites, which is also disseminated in the mica-slates, and is sometimes accompanied by sulphurets of lead, zinc and molybdenum (*Durocher*, *Ann. des Mines* [4], xv, 316). These associations should not be overlooked in the study of our Laurentian rocks, which may yet be found to be tin-bearing.

Another mineral which may possibly be met with in the Laurentian rocks of Canada is gold, since small quantities of the precious metal are found in several localities in Scandinavia, some of them probably, as that of Barbo, near Arendal, in rocks of Laurentian age. The gold of Scandinavia is, however, in such small quantities as to be nowhere made the object of mining. Details with regard to it are given by Daubrée (*Ann. des Mines* [4], iv, 265) and by Durocher (*Ibid.* [4], xv, 371). Small quantities of mercury, in the forms of cinnabar and silver-amalgam, are also found associated with galena at Sala in Sweden, in crystalline limestones, probably Laurentian. The notion that gold belongs only to rocks of Lower Silurian age, was many years since disproved by its discovery in the Upper Silurian slates of Eastern Canada, and more recently it has been shown that the great gold mines of California are in strata far more recent, and chiefly of the Jurassic and Triassic periods.

[Since the writing of this report, native gold has been found in the county of Hastings, under several conditions; first, associated with argentiferous fahlerz and with mispickel in small veins of bitter-spar, calcite and quartz cutting magnesian limestones, in Madoc; second, in a quartz vein in Marmora; and thirdly, in small irregular veins cutting magnesian limestone, with ferriferous bitter-spar, black hornblende, quartz and a black coaly matter, in which, as well as in the bitter-spar, the gold is disseminated in plates and crystalline scales. This last locality is also in Madoc, Ontario. See the Report of T. Sterry Hunt and A. Michel on gold in the county of Hastings, 1867.]

The existence of the Laurentian system in Bavaria and Bohemia, as already stated, has lately been established by Gümbel, both by stratigraphical and palæontological evidence. He finds in Bavaria an ancient gneissic series, estimated as not less than 90,000 feet in thickness, and by him divided into a lower portion, chiefly of red or variegated gneiss, which he calls the Bojian gneiss, and an upper portion, distinguished as the Hercynian gneiss. To this succeeds a series consisting chiefly of micaceous schists, with hornblendic and chloritic bands, overlaid by what he calls the Hercynian clay-slate formation, which immediately underlies the primordial zone of the Lower Silurian system. The prevailing character of the Hercynian gneiss is greyish, very quartzose, often containing black magnesian mica, and frequently having an admixture of oligoclase. Great portions of this gneiss are also marked by the presence of iolite or dichroite, giving rise to a distinct variety of rock, the so-called iolite-gneiss or dichroite-gneiss. Beds of hornblende slate, diorite and hornblendic gneiss are also abundant in this series, particularly in the vicinity of the limestone bands, and are often accompanied by beds of metallic sulphurets, and by lenticular masses and beds of graphite, which sometimes impregnates the beds to such an extent as to be wrought with profit. It is in these strata that the well-known plumbago deposits of the vicinity of Passau are found, under conditions closely similar to those of Canada and New York, in the same geological system. The crystalline limestone band near Passau, which occurs in hornblendic gneiss, is from fifty to seventy feet in thickness, and is directly overlaid by a bed of several feet of hornblende slate, between which and the limestone, a bed of three or four feet of serpentine is interposed, and in other parts a layer of nearly compact scapolite, mingled with hornblende and chlorite. The stratified granular limestone beneath contains, among other minerals, serpentine, chondrodite, hornblende, mica, scapolite, garnet and graphite ; the disseminated serpentine here, as in Canada, replacing the *Eozoon Canadense.*

The occurrence of iolite, as a frequent element in the Laurentian gneiss of Bavaria, is a fact of interest, inasmuch as it is also one of the minerals of the same ancient gneiss in Scandinavia, and may be looked for in this country, although it has not yet been detected in the undoubted Laurentian rocks of North America.*

The Hercynian clay-slate series of Bavaria, already referred to, and supposed by Gümbel to correspond to our Huronian series, includes a formation of crystalline limestones more than 300 feet in thickness, containing, like the older limestone of the Laurentian system, graphite, chondrodite, hornblende and serpentine, the latter two minerals replacing a peculiar and distinct species of Eozoon, named *Eozoon Bavaricum.*

Allusion has been made to the crystalline limestones which occur in Bolton and the adjoining towns in Eastern Massachusetts, and resemble in geognostic and mineralogical characters those of the Laurentian system. There are, however, not wanting reasons for supposing them to belong to a more recent geologic period, and the facts recently observed in Bavaria, and detailed above, show what was antecedently probable, that similar mineralogical characteristics may be found in crystalline limestones of very different ages.

In this connection, it is not without interest to recall the mineral characters of the rocks of Ceylon, which present many striking resemblances to the Laurentian strata of North America, and may perhaps be found to belong to the same system. The island was, so long ago as 1818, described by Dr. John Davy (*Trans. Geol. Soc.*, London, 1st series, v. 311) as made up of old feldspathic gneiss and gneissod limestone, together with granular crystalline limestone and dolmite, both in mountain masses and in veins, the latter sometimes white and lamellar, and enclosing spinel and apatite, prisms of yellow mica, cinnamon-stone garnet, yellow tourmaline and zircon, the latter two minerals associated with feldspar and quartz. The lamellar graphite, so abundant in the island, was regarded by Dr. Davy as the characteristic associate of the gems, spinel, zircon, garnet, etc. Anhydrite exists there in the gneissoid limestone, which he found to be impregnated also with sulphate of magnesia, nitre and nitrate of lime. In addition to these minerals may be mentioned sapphire and chondrodite, which are found together, imbedded in lamellar calcite, in Ceylon, and were mentioned by me in the *Report on the Geology of Canada* for 1847, page 134, as similar to those of our Laurentian rocks.

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* Iolite, as I have elsewhere remarked, is related to the feldspars, of which it has the atomic volume, and may be looked upon, chemically, as a feldspar, with the oxygen ratios, 5 : 3 : 1 (intermediate between labradorite and anorthite, and corresponding to barsowite and bytownite), in which magnesia, sometimes with protoxide of iron takes the place of lime and soda.

It is now proposed to consider the minerals of the limestones, with their accompanying beds of pyroxenite, gneiss, etc., which together constitute what we have denominated the limestone groups of the Laurentian system. When the mineral species occur disseminated in the stratified or indigenous rocks, and form an integral part of them, they will be designated as *bed minerals*, but when, on the contrary, they appear to belong to endogenous masses, occupying fissures or cavities in the strata, they will be spoken of as *vein-minerals.* The study of the species found under these two conditions will show that nearly all the minerals met with in the veins likewise occur disseminated in the strata, and will permit the inference that it is from the latter that the vein-minerals have all been derived. In the case of such as contain the rarer elements, however, it may well be supposed that these are so diffused through the mass of the sediments, that it was only when concentrated in the veinstones that they are capable of being recognized by mineralogical characters. It is nevertheless evident that, in certain cases at least, the particles of the sedimentary strata have at one time possessed a sufficient mobility to permit of crystallization, and of a partial segregation and grouping of their heterogeneous elements.

In the following list are included all the minerals, so far as yet known, which may be regarded as belonging to the Laurentian limestones of North America, and their immediately related strata. In addition to the rocks of this denomination in Canada, and in northern New York, are to be added those of the Highlands of the Hudson, and their extension in Orange county, New York, and in Sussex county, New Jersey. The observations of Prof. J. Hall and Sir William Logan upon these rocks in the Highlands, have confirmed the views of those who had previously asserted them to be older than the Lower Silurian series, and shown that they are doubtless of Laurentian age. This more southern area is much better known and explored than the comparatively wild and uncultivated Laurentian region of Canada, yet with the exception of the remarkable zinciferous minerals, franklinite, red zinc ore, willemite and dysluite, which are confined to a small section in New Jersey, nearly all the mineral species of these limestones found in the United States have already been recognized in Canada.

Minerals of the Laurentian Limestones of North America.

Calcite.
Dolomite.
Fluor-spar.
Heavy-spar.
Apatite.
Serpentine.
Chrysolite.
Chondrodite.
Tephroite.
Willemite.
Wollastonite.
Hornblende.
Pyroxene.
Babingtonite.
Pyrallolite,
Talc.
Gieseckite.
Loganite.
Scapolite.
Orthoclase.
Oligoclase.
Phlogopite.
Margarite.
Clintonite.
Tourmaline.
Garnet.
Idocrase.
Epidote.
Allanite.
Zircon.
Spinel.
Völknerite.
Corundum.
Quartz.
Sphene.
Warwickite.
Ilmenite.
Rutile.
Magnetite.
Hematite.
Franklinite.
Zincite.
Cubic pyrites.
Magnetic pyrites.
Copper pyrites.
Mispickle.
Fahlerz.
Bismuthine.
Blende.
Antimony glance.
Molybdenite.
Gold.
Graphite.
Anthracite.

No one bed or vein probably has ever been found to include all the mineral species of the above list, yet the composition of some of these veinstones is nevertheless very complex, as may be seen by the following examples. The first is from my own observation of the vein on the tenth lot of the fifth range of Grenville, Ontario, which cuts a crystalline limestone holding scales of mica and graphite, and has itself been mined as a source of the latter mineral. The minerals found in this vein are calcite, apatite, serpentine, wollastonite, pyroxene, scapolite, orthoclase, oligoclase, garnet, idocrase, zircon, quartz, sphene and graphite—fourteen species in all. A still larger number has been observed by Mr. W. P. Blake in a single vein, traversing crystalline limestone, in Vernon, Sussex county, New Jersey. He there found calcite, fluor-spar, chondrodite, hornblende, phlogopite, margarite, red spinel, red corundum, zircon, sphene, rutile, ilmenite, pyrites and graphite, to which list he adds "hydrous peroxyd of iron, and hydrous silicates of alumina" (*Amer. Jour. Science* [2], xiii. 116).

These veinstones, as will be seen from numerous examples in the following pages, are found traversing alike the limestones and their various associated strata. In an instructive instance in the Cheever ore-bed at Port Henry, New York, a vein is found in a bed of magnetic iron, of which it includes angular fragments. The veinstone, for specimens of which I am indebted to Prof. Hall, consists of cleavable masses of a greenish triclinic feldspar, pyramidal crystals of quartz with rounded angles, octahedrons of magnetite, a substance resembling allanite, with a specific gravity of 4.09, and a dark green mineral with the cleavage of pyroxene, but having the hardness and specific gravity (2.713) of loganite. All of the elements of this remarkable aggregate with the exception of the magnetite, are in masses of an inch or more in diameter.

CALCITE.—In many of the veins traversing the strata of the limestone group, calcite is entirely wanting, or is present only in small portions; but in others it occurs in large quantity, and so far predominates that the veinstone is readily mistaken for a crystalline limestone, generally coarse, but sometimes very fine grained, which is occasionally white, but more frequently yellowish, pink, flesh or salmon colored, and rarely pale blue. These ancient calcareous veinstones are sometimes nearly free from foreign minerals, but more frequently include crystals, often of large dimensions, of apatite, magnesian mica, pyroxene, brown tourmaline, and other minerals. Drusy cavities, in the veins of mingled calcite and apatite in Burgess, are sometimes lined with large crystals of dog-tooth spar. We have already insisted on page 48 upon the fact, which is there for the first time pointed out, that it is these highly calcareous veinstones which have given rise, in North America at least, to the widely-spread notion of the eruptive origin of crystalline limestones.

Of calcite as a bed-mineral, constituting great stratified masses of limestone in the Laurentian series, it is not necessary here to speak. It is, however, to be remarked that in these limestones, as in those of later periods, we have now evidence that portions of the carbonate of lime once belonged to living organisms, as is shown in the calcareous skeletons of the Eozoon. These, though sometimes preserved by injection with silicates, appear in other cases with their tubes and canals filled with carbonate of lime, evidently—like the silicates—a chemical deposit, and there is no doubt that a part of these limestones, like those of more recent formations, have been directly precipitated by chemical reactions from the waters of the ocean. The often repeated assertion that organic life has built up all the great limestone formations, is based upon a fallacy, for animals have no power to generate carbonate of lime. Although many invertebrate animals construct calcareous skeletons, which form a great part of the limestone of the earth's crust, the pre existence of this carbonate of lime is one of the conditions necessary to their growth, and, as I have elsewhere shown, owes its origin to chemical reactions which are still going on in the ocean's waters, and which have in past times given rise directly to limestone strata, in which the occurrence of shells and corals is only accidental (*Geol. Can.*, pages 575, 631).

DOLOMITE.—As already pointed out in the *Geology of Canada*, pages 24 and 592, large beds of the Laurentian limestones are magnesian, and sometimes have the composition of true dolomites. These dolomites and magnesian limestones have been found to contain serpentine, hornblende (tremolite), apatite, quartz and small portions of mica, and they may, perhaps, in different localities, include all those mineral species which have been indicated as belonging to the limestone strata. It is to be remarked that the calcareous skeleton of *Eozoon Canadense*, which is carbonate of lime, is found, in specimens from Burgess, replaced by dolomite.

The mineral filling the chambers of the fossil is in this case loganite, but the delicate tubuli, which are preserved in the Eozoon from most other localities, have almost entirely disappeared; a fact perhaps connected with the removal of the calcareous skeleton, and its replacement by dolomite.

As a vein-mineral, dolomite has been but seldom observed in the Laurentian veins. A magnesian carbonate of lime is, however, found in two localities in North Burgess, in one case forming the gangue of apatite crystals, and in the other of prisms of brown mica. The analysis of the yellowish sparry carbonate, in the latter instance, showed it to contain, besides carbonates of lime and magnesia, a notable amount of carbonate of iron and a little carbonate of manganese. These complex carbonates require further study. The interesting results obtained by Jenzsch in the analysis of a similar white sparry carbonate, which, at Sparta, New Jersey, forms the veinstone of the red zinc ore and franklinite, deserve to be recalled in this connection. He found the spar to contain carbonate of lime 79.96, carbonate of magnesia 1.94, carbonate of manganese 11.09, carbonate of iron 0.60, carbonate of zinc 0.58, besides 5.39 per cent. of fluorid of calcium, an ingredient which he has also detected in the calcareous spar of several other localities (*Amer. Jour. Science* [2], xxi, 197).

Fluor Spar.—Inasmuch as fluorid of calcium enters into the composition both of the calcite and the apatite of these calcareous veins, we are prepared to find it separately crystallized, as fluor-spar, which occurs in several localities among the Laurentian limestones of the United States, in veins with scapolite, chondrodite, pyroxene, spinel, and other characteristic species. In Canada it is met with in Ross, Ontario, in small purple cleavable grains, imbedded, with prisms of apatite and large crystals of spinel, in what has been described in the *Geology of Canada*, pages 461 and 463, as a yellowish white crystalline limestone, and which, from its mineralogical characters, will probably be found to be a veinstone. In addition to this, a small vein, filled with cleavable purple fluor-spar, was observed in the vicinity. The purple fluor which occurs with red heavy-spar, in fissures or cavities in the limestone associated with the hematite of Iron Island, in Lake Nipissing (*Geol. Can.*, pages 456 and 463), is probably also a veinstone mineral, and I know as yet of no certain evidence that fluor occurs as a distinct species among the Laurentian bed-minerals.

Heavy-Spar.—The heavy-spar found in the Laurentian rocks, generally belongs to the recent or lead-bearing veins, but sometimes appears in the older veins. In addition to that just mentioned as occurring at Iron Island, small quantities of flesh-red lamellar sulphate of barytes are found with quartz, implanted on apatite, in a vein in Burgess.

Apatite.—This is one of the most abundant minerals in the Laurentian veinstones, of which it sometimes constitutes the entire mass, appearing, as described on page 761 of the Geology, as a crystalline, homogeneous rock, translucent, with an uneven fracture, a vitreous lustre, and a grayish color, passing into greenish or reddish. It then resembles in its aspect some varieties of quartzite, and at other times consists of incoherent grains, resembling a disintegrating sandstone. Another variety is more coarsely crystalline, sea-green in color, and, like the last, intermixed with a little black mica. In this instance, large and distinct prisms of apatite, with rounded angles, are observed penetrating the confusedly crystalline mass of the same mineral, which has apparently been deposited upon and around them. The locality of this variety is on the twenty-fifth lot of the eighth range of North Elmsley, Ontario (which is described in the Geology as a bed, but is probably a vein). There, adjoining three feet of nearly pure apatite, is found an admixture of crystals of apatite with crystalline flesh-colored carbonate of lime, accompanied by loganite and sphene. In several other localities in this region, outcrops of a precisely similar aggregate are found, which would be described as crystalline limestones, generally reddish or pink in color, and including crystals and irregular crystalline masses of green apatite, sometimes associated with large prisms of magnesian mica. In those places where it has been possible to determine the attitude of these aggregates, it is very evident that they are true veinstones, cutting the bedded rocks of the country. Crystals of apatite several inches in diameter are often met with, and one in the Museum of the Geological Survey is eighteen inches long and twenty-six inches in circumference, and weighs about one hundred pounds. Like all the apatite crystals from this region, its lateral and terminal angles are very much rounded. The apatite crystals of these veinstones are generally of some shade of green; but in Ross, crystals of a reddish-brown color are met with, and others of an olive-green, passing into wax-yellow, imbedded with purple fluor, in carbonate of lime.

The crystals of apatite from these veinstones sometimes include rounded crystals of quartz, or of carbonate of lime, and on the contrary are sometimes themselves imbedded, not only in carbonate of lime and dolomite, but in massive apatite, in quartz, in mica, or iron pyrites, in foliated graphite, and probably in other minerals. In one case, a crystal of apatite one-fourth of an inch in diameter and two inches long, was found imbedded in a large crystal of mica, one end only projecting from the side of the mica prism, with which the prism of apatite was at right angles. In Ross, crystalline grains of yellow apatite are imbedded in octahedrons of black spinel. As already stated, prisms of apatite, often of large dimensions, line drusy cavities in the veins of massive apatite, or of mingled apatite and pyroxene. In the latter case, large crystals of the two species are sometimes found grouped together like those from Snarum, in Norway. In the specimens from the latter locality, however, unlike those from Burgess, the apatite prisms preserve their sharpness of outline, and, as well as the accompanying pyroxene, are partially incrusted with quartz crystals.

Apatite occurs in the veins in Burgess incrusted with crystals of quartz, sometimes, smoky, ferruginous, or amethystine, and at Ticonderoga, New York, crystals of apatite are imbedded in massive vitreous quartz. The radiated and botryoidal apatite, named eupyrchroite by Emmons, is worthy of notice as a peculiar form of the mineral ; it occurs with quartz, brown tourmaline and allanite, filling a vein at Ticonderoga. The mineral from North Burgess, as shown in the *Geology of Canada*, belongs to the variety fluor-apatite, the analysis of a pure massive specimen having given me phosphate of lime 91.20, fluorid of calcium 7.60, chlorid of calcium 0.78, insoluble 0.90 = 100.48.

Apatite as a bed-mineral is very frequent, both in the limestones of the Laurentian system and their associated rocks. Small crystals of it are often disseminated through the limestone beds, generally in very small proportion, but in some cases rising to two or three per cent, or even a much larger amount, though still in the form of grains or small crystals, often with pyroxene. These larger proportions of apatite appear to characterize certain beds or bands in the limestone.

Apatite also occurs disseminated in grains or small masses, marking the stratification in the beds of the pyroxenite, and in one instance, to be described further on, was observed forming a small interrupted bed in this rock. The magnetic iron ore, which often forms beds in the immediate vicinity of the limestones of the Laurentian series, and, like the pyroxenite, is to be regarded as belonging to the limestone groups, contains in some places in New York, a large admixture of grains or small prisms of apatite, generally reddish-brown, but sometimes colorless, and occasionally associated with grains of green pyroxene. Specimens of a similar aggregate of magnetite and apatite are said to have been found on the Ottawa; and it is worthy of remark that the extensive beds of iron ore found in Laurentian rocks in Grangjärde in Sweden, and consisting of an admixture of magnetic and specular oxyds, very generally contain grains of apatite, whose presence is supposed to depreciate the quality of the iron there manufactured. (*Durocher*, *Ann. des Mines* [4], xv, 249).

Serpentine.—This species, though not very common in the Laurentian veinstones in Canada, sometimes occurs in small disseminated grains, or in crystals of considerable size, inbedded in calcite. Examples of this occur in North Burgess, where, in one locality, imperfectly defined crystals, an inch in diameter, and in another, small grains, with corundum, sphene, mica and pyroxene, are found; in both cases imbedded in calcite. A massive serpentine also occurs, forming the gangue of large crystals of mica in northern New York. The large crystals of serpentine (sometimes enclosing a nucleus of chrysolite) from Snarum in Norway, which, according to Scheerer, are accompanied with mica, and imbeded in ilmenite, or in magnesite, in the midst of gneiss, probably belong to a vein. Crystals resembling them occur in New York (*Amer. Jour. Science* [2], xvi.)

Distinct from these veins are the small seams filled with fibrous serpentine or chrysotile, which are frequently found traversing the massive serpentines, or the mixtures of serpentine and limestone which make up great beds in the Laurentian series. Massive translucent serpentine often occurs as the mineral replacing the *Eozoon Canadense*, the canals of which are in such cases injected with this silicate. In some cases the unbroken calcareous skeleton of the fossil is preserved in the serpentine, while in others, only broken and detached fragments of the skeleton are found, sparsely distributed through the serpentine. The presence of disseminated grains of serpentine, in greater or less abundance, characterizes beds, both of pure limestone and of dolomite, in the Laurentian series; and beds of pure, or nearly pure, serpentine are also met with, sometimes enclosing scales of mica, grains of calcite, which, under the microscope, are seen to be fragments of Eozoon, or finely disseminated peroxyd of iron, which gives to the serpentine a deep red color. Concretionary masses of serpentine, sometimes exhibiting in the arrangement of different colors a banded or agatized structure, are often met with, imbedded in the limestones, and generally have a nucleus of white granular pyroxene. These masses may vary from a few inches to a foot or more in diameter.

I have already elsewhere described the composition of the Laurentian serpentines, their low specific gravity and pale colors—characters which are due to the small amount of oxyd of iron, and the large proportion of water (equal to about fifteen per cent) which enters into their composition. These characters, together with that of the constant absence from them of chrome and nickel, serve to distinguish the Laurentian serpentines of North America from most others known, and to connect them with those from the old rocks of Scandinavia, with which they have a close resemblance.

An analysis of the chrysotile from a narrow vein traversing the Eozoon rock of Petite Nation seigniory, Quebec, gave me, silica, 43.65; magnesia, 41.57; protoxyd of iron, 1.46; water, 13.48=100.16.

Chrysolite.—This species, which is found in the crystalline limestones of Somma, and, according to Rose, occurs with the serpentines of Snarum, is known in the crystalline limestones of Bolton, Massachusetts, under the name of boltonite, which Messrs. Lawrence Smith and Brush have shown to be a pure magnesia-chrysolite. I place it in the list of Laurentian minerals, on the authority of Messrs. Horton and Beck, according to whom, boltonite occurs in several localities in limestone, associated with spinel and hornblende, in Orange county, New York (*Beck, Mineralogy of New York*, page 283). It is not improbable that this mineral may be more widely diffused, and it has perhaps been confounded with chondrodite, like which species, and like serpentine, it will probably occur both in beds and in veinstones.

Chondrodite.—This fluosilicate of magnesia occurs in calcareous veins, generally with spinel, in numerous localities in the United

States, but I have as yet noticed it in Canada only in beds, where disseminated grains of chondrodite mark the places of stratification in the limestone. In one instance, in a specimen of limestone from an unknown locality, the contact of two layers, one marked by grains of chondrodite, and the other by grains of serpentine, is distinctly seen. A similar association of the two minerals occurs at St. Jérôme, in the province of Quebec.

TEPHROITE, WILLEMITE.—These two rare species, the first a silicate of manganese, and the second a silicate of zinc, both of them having the general formula of chrysolite, with which the former is isomorphous, have hitherto only been observed in North America, in Laurentian veins, crystallized with the franklinite and red zinc ore of Sterling, New Jersey, and its vicinity.

WOLLASTONITE.—This species forms considerable masses in the large vein already noticed in Grenville, where its associates in the veinstone are pyroxene, orthoclase, quartz, apatite and sphene. In smaller specimens it occurs with the same associates in a vein in North Elmsley, while in Willsborough, New York, it is found also in a vein with grains of green pyroxene, and red granular garnet, which latter in some part predominates to the exclusion of the other minerals.

As a bed-mineral I have observed it in North Burgess, sparsely disseminated in a limestone, with small quantities of green pyroxene, brown mica and apatite. In the same vicinity, interstratified with pyroxenite, are interrupted beds of rock made up of quartz and wollastonite. Similar associations to these occur elsewhere in the Laurentian strata.

HORNBLENDE.—The hornblende of the Laurentian limestones is either in the form of tremolite, or more frequently in green prismatic crystals belonging to the variety called pargasite. The raphilite, a grayish fibrous hornblende, allied to tremolite, occurs apparently in a vein with quartz, mica, apatite and calcite. Large well-defined crystals of dark green pargasite are found implanted upon or imbedded in still larger crystals of pale-green pyroxene, in a vein described by Sir William Logan as occurring near the High Falls on the Madawaska, Ontario, cutting across alternating strata of gneiss and limestone, and having a breadth of not less than one hundred and fifty feet. The minerals filling this immense vein are chiefly a pale grayish-green pyroxene (sahlite), pargasite, calcite, quartz, mica and black tourmaline, the crystals of the first named mineral being sometimes six inches thick, and as much as twenty-four inches in length, and those of the dark green hornblende occasionally an inch both in length and breadth. (See *Geol. Can.*, pages 35 and 466). This association of pyroxene and hornblende has been observed elsewhere in the Laurentian rocks (page 49). Pargasite is frequently found in the apatite veins in Burgess, and sometimes forms the selvage of the vein where this cuts a hornblendic gneiss. Although this species frequently occurs in the gneissoid rocks near the crystalline limestones, it is less frequent, as a disseminated mineral in the limestones, than pyroxene. In the stratified pyroxenite rocks, small portions of hornblende, recognizable by their different crystallization and their darker green color, are not unfrequent. In some localities it appears to take the place of the pyroxene, and large beds of hornblende rock, passing into diorite and hornblendic gneiss, are met with. A radiated green hornblende, actinolite, is sometimes found imbedded in the magnetic iron ores.

PYROXENE.—Repeated mention has already been made of the important rank which this species assumes in the Laurentian veinstones, in which the varieties diopside, sahlite or coccolite often form the predominant mineral. Its crystals are sometimes found, either alone or with mica, imbedded in calcite, or in contact with hornblende, wollastonite, orthoclase, scapolite, garnet, apatite, spinel, zircon or sphene. It often assumes a granular form, constituting what is called coccolite. A white aluminous diopside is found with apatite, gieseckite, etc., in Bathurst, Ontario (*Geol. Can.*, page 467), and the hudsonite of Orange county, New York, is a black aluminous pyroxene.

We have already mentioned the pyroxenite rocks, sometimes micaceous, and at other times mixed with hornblende, or with orthoclase, quartz and sphene. Pyroxene also sometimes occurs disseminated in the beds of magnetite, and grains or imperfect crystals of it, generally of a green color more or less deep, are common in the beds of limestone, and are also sometimes found in the associated quartzites. A pure white granular pyroxene occurs, replacing, like serpentine, *Eozoon Canadense.* Large masses of a similar pyroxene are also frequent in these limestones, generally associated with serpentine, which often incrusts it, and small nuclei of this pyroxene frequently form the centre of concretionary masses of serpentine.

Babingtonite.—This rare species, which belongs to the pyroxene group, is said to be found upon crystals of feldspar in Gouverneur, New York, and occurs under similar conditions in veins near Arendal in Norway.

Pyrallolite.—This species, the rensellaerite of Emmons, occurs in one locality in radiating columnar masses, with quartz, in a vein, and is also met with in beds, in contact with serpentine, with pyroxenite, and in another case with limestone, and enclosing scales of mica and of graphite (*Geol. Can.*, page 470). A compact earthy hydrous silicate of magnesia, having the characters of meerschaum or aphrodite, and the composition of the latter, occurs in cavities in massive rensellaerite in Grenville (*Ibid.* page 473).

Talc.—This species is closely related to the last, and the two may be looked upon as dimorphous conditions of the same hydrous silicate of magnesia. In the Laurentian series, talc seems to be generally replaced by pyrallolite, but in one instance is observed mixed with carbonates of lime and magnesia, in such proportions as to give rise to a bed of impure steatite (*Ibid.* page 469). Prof. H. D. Rogers has also indicated talc as occurring in a vein, with calcite, pyroxene and spinel, in Sparta, New Jersey.

Gieseckite.—This mineral, which the careful researches of Prof. G. J. Brush have shown to be identical with the rock named dyssyntribite by Prof. C. U. Shepard, and with what I formerly described as parophite, is found in large crystals in northern New York, associated with calcite, brown pyroxene and mica, the aggregate doubtless constituting a veinstone. Wilsonite, which, notwithstanding its apparently distinct cleavage-form, I have provisionally included under the head of gieseckite, with which it is almost identical in composition, hardness and gravity, occurs also in a veinstone, in Bathurst, with calcite, apatite, white aluminous pyroxene and serpentine. The mineral which I once described by the name of algerite, is found in white calcite, among the Laurentian limestones of Franklin, New Jersey, and has a composition similar to that of gieseckite, although the form of the crystals appears to be a square prism. Whatever conclusions may eventually be arrived at relative to these hydrous silicates of alumina and potash, the assumption that they are results of a supposed alteration of nepheline, scapolite, etc., is purely gratuitous.

The occurrence of beds of this compound, more or less pure (dyssyntribite and parophite), as a massive or schistose rock, alike in the Laurentian and Silurian series, leads us to assign to it a rank and an origin among such rocks as serpentine, steatite, pyroxene, chlorite, glauconite and epidote, all of which silicates, and many others, have been in most cases deposited as aqueous sediments generated by chemical reactions at the earth's surface, and in many cases subsequently modified by crystallization, or molecular re-arrangement (*Geol. Can.*, page 581.)

As I have elsewhere remarked, although sparry in structure, gieseckite and wilsonite have very nearly the chemical composition of the hydrous potash-mica, margarodite. In like manner the sparry silicates, pyrallolite and loganite, correspond to the foliated species, talc and pyrosclerite, of which they have the elementary composition, although differing entirely in structure (*Ibid.* page 492).

Loganite.—This prismatic hydrous species, which I first described in 1848, has recently acquired a new interest. It occurs in several places as a veinstone, in one case filling the central portion of a vein of apatite, and inclosing calcite and sphene; and in another, in considerable masses, with large crystals of mica, imbedded in a great vein of pyroxene. Evidence of its occurrence as a sedimentary mineral is afforded by the fact that in one locality it forms the enclosing and filling material of the Eozoon.

[This species, numerous analyses of which will be found in the *Geology of Canada*, page 491, has been by Dana (*Mineralogy*, 4th edition) referred to pyrosclerite, which he however described as possessing an eminent basal cleavage, and in fact identical with the foliated micaceous minerals kaemmererite and vermiculite. I have maintained the distinctness of loganite from these, first, from the greater amount of water in its composition, and, secondly, from the entire absence of foliated or micaceous structure. Specimens declared to be the original pyrosclerite from Elba, which I have since examined, have, however, a sparry aspect, and a cleavage resembling that of pyroxene and loganite. The difference in composition between loganite and pyrosclerite still remains to be got over; but if these two minerals are to be identified, neither of them can be confounded with kaemmererite or vermiculite, from which they differ as pyrallolite does from talc.]

In the *Geology of Canada*, page 490, attention has been called to several other hydrous alumino-magnesian silicates approaching to loganite in composition, and resembling serpentine or pyrallolite in sensible characters. Two of these, described and analyzed by Dr. Beck, occur in the Laurentian limestones of Orange county, New York. These form altogether an interesting and but little understood group of minerals, which are perhaps most important in the history of the crystalline limestones than has hitherto been supposed.

ORTHOCLASE.—This species is common in Laurentian limestones, generally with pyroxene and sphene, and sometimes accompanied by scapolite or a triclinic feldspar. The orthoclase of the veins is, as I have shown, sometimes a very pure potash-feldspar, while the variety named loxoclase by Breithaupt, which occurs with pyroxene in a Laurentian vein in Hammond, New York, was found by Smith and Brush to have a predominance of soda (*Geol Can.*, p. 475). Large isolated crystals of white orthoclase are found, with spinal, apatite and fluor, in a veinstone of lamellar pink carbonate of lime in Ross. The perthite of Burgess, which probably belongs to a granitic veinstone, is also an example of an orthoclase with a large amount of soda.* An orthoclase, reddish-brown in color, like the perthite, but without its aventurine-like reflections, also occurs in Burgess, mixed with a little quartz, and sometimes with green apatite, in the midst of a large vein chiefly of apatite and calcite, forming a granite-like vertical layer, equidistant from the two walls of the vein. Orthoclase is sometimes disseminated in the beds of pyroxenite which accompany the Laurentian limestones, and are in that case interstratified with beds of an aggregate of orthoclase and quartz, forming a granitic gneiss, into which the pyroxenite graduates.

OLIGOCLASE.—To this species I refer provisionally, a white translucent triclinic feldspar, which occurs in small masses with orthoclase, pyroxene and sphene in a vein at Grenville, already noticed. A similar white feldspar, recognizable by the beautiful striation of its cleavage planes, occurs with pyroxene and sphene in Willsborough, New York, and a dark green triclinic feldspar is found with apatite, pyrites and magnetite near Dover, New Jersey, and with magnetite and allanite at Port Henry, New York. None of these, so far as I am aware, have been analysed. The peristerite of Thompson, which, as I have shown, is an opalescent albite, containing, however, a small portion of lime, belongs to a Laurentian veinstone, and is accompanied by quartz and orthoclase.

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* It has since been shown by Gerhard to be made up of thin layers of reddish orthoclase and whitish albite. See *Dana's Mineralogy*, fifth edition, page 356. T. S. H.

Portions of a feldspar are occasionally intermixed with the pyroxenic and hornblendic strata accompanying the Laurentian limestones. This in some cases is orthoclase, as remarked above, but at other times is evidently a triclinic species, giving rise by its admixture with hornblende to a kind of diorite. The great beds of rock, composed chiefly of labradorite or related triclinic feldspars, which have been elsewhere described as belonging to the Laurentian system, occur in that upper and unconformable division which has been designated as the Upper Laurentian or the Labrador series.

Scapolite.—Under the head of scapolite and its various synonyms, mineralogists have included a number of dimetric silicates allied to the feldspars, and sustaining to one another relations similar to those of the different triclinic feldspars; the extremes being dipyre, the least basic, and meionite, the most basic of the series. Scapolite abounds in many of the Laurentian veinstones, often associated with pyroxene or sphene (sometimes with orthoclase), and frequently in detached crystals, imbedded in calcite. It will not improbably be found in the crystalline aggregates which make up some of the stratified rocks of the series, and has been observed by Gümbel under such conditions in Bavaria. See pages 47 and 67.

Phlogopite.—The crystallized mica of the Laurentian calcareous veinstones is a magnesian mica, and belongs to the species phlogopite or biotite. The crystals, which occasionally afford laminæ two feet square, are found imbedded alike in calcite, dolomite, apatite, serpentine and pyroxene. Packed close together, with but little intervening matter, large crystals of magnesian mica sometimes line the walls of veins whose centre is filled with apatite. The laminæ of the large mica crystals are often contorted, and sometimes hold between them thin plates of calcite or quartz, or flakes of plumbago. In one case already noticed, a well-formed crystal of apatite was found imbedded in a prism of mica, which had evidently crystallized around it. Some of the finest crystals of mica of moderate size occur imbedded in serpentine, or with crystallized pyroxene, in calcite.

Small plates of mica, probably a magnesian species, abound both in the limestone beds and the pyroxenites, and sometimes form layers of a schistose mica-rock, interstratified with the latter. Non-magnesian micas, belonging to the species muscovite, margarodite or lepidolite, are occasionally found in the quartzo-feldspathic veins of the Laurentian series, where compounds of lime and magnesia are wanting; but it is not certain whether they ever occur with the calcareous veins or beds. As already remarked, the chemical composition of gieseckite, and of the minerals which we have provisionally associated with it (wilsonite, algerite and dyssyntribite) is identical with the hydrous mica, margarodite, which is thus represented in the Laurentian series by these sparry silicates, precisely as talc is there represented by pyrallolite (*Geol. Can.*, pages 482–486 and 492).

Margarite.—This species, the emerylite of Dr. J. Lawrence Smith, which may be regarded as a hydrous lime-mica, is mentioned by Blake as occurring with corundum, spinel and calcite in a Laurentian veinstone in Vernon, New Jersey, but has not been elsewhere identified.

Clintonite.—This mineral, somewhat related in composition to the preceding species, occurs in several localities in Orange county, New York, with spinel and chondrodite, in calcareous veinstones. It has also been observed, with small crystals of blue spinel, in a calcareous matrix, in Daillebout, Quebec.

Tourmaline.—This species frequently occurs in the calcareous Laurentian veins, with pyroxene, hornblende, apatite and calcite. The finest crystals of brown tourmaline in Canada have been found in veinstones of flesh-colored calcite, either with or without pale green pyroxene, or in a veinstone of translucent quartz. Black tourmaline is also occasionally found with pyroxene, but is more generally met with in the granitic veinstones, with orthoclase and a non-magnesian mica. Tourmaline, in grains or imperfect crystals, also occurs in the stratified rocks of the series. In one instance it appears in small knot-like masses, in an impure grayish limestone, apparently marking the planes of stratification.

Garnet.—This mineral frequently occurs in the veins, sometimes imbedded in orthoclase or in quartz, at others in calcite, or, as at Willsborough, New York, forms granular masses, associated with wollastonite and pyroxene. Garnet is moreover of frequent occurrence in the strata associated with the limestones, sometimes disseminated in grains in the pyroxenites, and more often in accompanying beds of quartzite, in which it sometimes forms layers of red garnet rock. The strata of gneiss in the vicinity of the limestones often abound in garnet.

IDOCRASE.—This species, although less abundant than garnet, is found in several places associated with it. The occurrence in a vein of a skeleton-crystal of yellow idocrase, enclosing orthoclase and zircon, has been noticed on page 50. The same vein affords crystals of cinnamon-stone garnet. I have elsewhere described a boulder of crystalline carbonate of lime, apparently a veinstone, found on the Ottawa, in which were detected small square prisms of idocrase, dodecahedrons of garnet, and terminated triangular prisms of tourmaline, all three species being of a bright yellowish-brown color.

EPIDOTE.—This species occurs in several localities in calcareous veins among the Laurentian rocks in New York and New Jersey, sometimes crystallized with orthoclase, pyroxene and graphite, or as described by Prof. Henry Wurtz, imbedded in fine crystals in calcite, in Byram, New Jersey. A specimen from Cold Spring, New York, exhibits a crust of small crystals of epidote coating a large prism of pyroxene. Although not hitherto detected in any of the Laurentian veins in Canada, epidote enters largely into the composition of the pyroxenic and feldspathic rocks which are associated with the limestones in the vicinity of the iron ores of Belmont and Seymour, Ontario.

ALLANITE, which is regarded as a cerium-epidote, occurs in some of the Laurentian veins, associated with apatite and tourmaline at Ticonderoga, and with quartz, feldspar and magnetite at Port Henry, New York.

ZIRCON.—This species is of frequent occurrence in the calcareous veins, associated with pyroxene, hornblende, orthoclase, scapolite and sphene. In Munroe, Orange county, New York, crystals of zircon abound in a gangue of magnetic iron ore with pyroxene and feldspar, and according to Durocher, zircon is also met with in the magnetic iron of Solberg, near Arendal, and at Langsoë in Norway (*Ann. des Mines* [4], xv, 229). Zircon is also found disseminated in large proportion in a gangue of black hornblende with a little feldspar, in Cornwall, Orange county. Large and well-defined prisms of zircon, which occur with apatite and feldspar in Hammond, St. Lawrence county, New York, are sometimes, like the idocrase noted above, skeleton crystals, filled with carbonate of lime (*Beck. Mineralogy of New York*, page 381).

Spinel.—This mineral is often abundant in the calcareous Laurentian veins, generally associated with chondrodite, pyroxene, clintonite, serpentine, ilmenite, and other species. Sometimes it is imbedded in calcite without any other mineral, as in Burgess, where a mass of pink limestone, probably a veinstone, has afforded fine crystals of black spinel an inch in diameter. In Ross, similar crystals occur in a calcite vein with orthoclase, fluor-spar and apatite; grains of the latter mineral are frequently imbedded in the spinel crystals. Small crystals of spinel are sometimes found disseminated in what appear to be stratified limestones. Although the spinel of the Laurentian limestones is generally black, blue, red and green varieties are occasionally met with. The dysluite or zinciferous spinel is worthy of notice, as occurring in Stirling, New Jersey, with other zinc-bearing minerals.

Volknerite.—To this species, a hydrous aluminate of magnesia, Dana has referred the houghite of Shepard, from St. Lawrence county, New York, which occurs associated with crystals of spinel, and having the same octahedral form, but distinguished by a low specific gravity, and a softness like steatite. A gradation is seen from the hard spinels to the houghite crystals, which still include a portion of spinel, but consist chiefly of a matter having the composition of völknerite. It would seem that the crystallogenic force of the spinel has given its form to accompanying völknerite. Small steatitic octahedrons, apparently similar to the houghite, have been found imbedded in serpentine, in Burgess, but require farther examination. The hydrotalcite, which is regarded as identical with völknerite, occurs with ilmenite in the Laurentian serpentine of Snarum, in Norway.

Corundum.—Crystallized corundum, white, blue or red in color, occurs with associations similar to those of spinel, which occasionally accompanies it. Crystals of corundum line cavities in the large spinels from Orange county, New York. The red crystals from Vernon, New Jersey, as described by Blake, like the idocrase and zircon mentioned above, often present a mere outer shell of corundum filled up with other minerals. The corundum found in Canada is imbedded in calcite with pyroxene, sphene and mica, and very closely resembling those associated with it at Vernon.

Quartz.—The presence of crystalline quartz in the Laurentian veinstones has already been repeatedly noticed. Sometimes, as at Gouverneur, New York, it is found in crystals with rounded angles imbedded in crystalline calcite ; at other times implanted on apatite, as in Burgess, where the crystals are occasionally amethystine, smoke-brown or opaque-red in color, and unlike the apatite, to which they are posterior, have not their angles rounded. Quartz is of very common occurrence in the veins, mingled with wollastonite, pyroxene or orthoclase, and a vitreous quartz is sometimes the gangue of crystallized brown tourmaline and of apatite. It is also frequently disseminated in grains or small masses in the limestone beds, or forms in the accompanying strata layers, in which it is sometimes mingled with wollastonite, with green pyroxene, with garnet, or with orthoclase. Besides these, thin layers and massive beds of quartzite are frequent, and are often interstratified with the limestones.

Sphene.—This is one of the most common minerals of the calcareous Laurentian veins, and its occurrence and associations have already been repeatedly mentioned. It also occurs in small grains or crystals, generally olive-brown in color, disseminated in the stratified limestones, or more frequently in the associated pyroxenic and feldspathic strata.

Rutile—Ilmenite.—Both of these species are occasionally found crystallized in Laurentian veins with spinel, chondrodite, corundum, etc., or imbedded in serpentine. The imbedded grains and masses of ilmenite, often of great size, and sometimes intermixed with rutile, which occur at Bay St. Paul, Château Richer, and elsewhere in the province of Quebec, appear to belong to the Upper Laurentian or Labrador series, and neither of these minerals have as yet been met with in the proper Laurentian rocks in Canada, although occuring in several localities in New York. The ilmenite crystals, with serpentine, from Snarum, and with hornblende and calcite from Krageroë, are well known to mineralogists.

Magnetite.—This important iron ore, which constitutes one of the principal sources of mineral wealth to the Laurentian regions both of North America and of Scandinavia, has been shown by the explorations of the Geological survey in Canada to occur in great beds, interstratified with the limestones of the series or in their vicinity. This is clearly the case with all the considerable deposits of ore hitherto examined in Canada ; yet, as in the case of the crystalline limestones, there are those who maintain the eruptive character and igneous origin of these masses of ore. Emmons looked upon the magnetic iron ores of northern New York as intrusive masses, and Prof. H. D. Rogers in like manner regarded the magnetic iron ores of the Laurentian strata of New Jersey not as beds, but as real veins of injection (*Final Report*, *Geol. N. Jersey*, page 22). Durocher in like manner, in describing the deposit of the same ore at Bispberg in Sweden, speaks of it as a "plutonic rock" injected among the beds of gneiss in the plane of stratification, and having a thickness of from eighty to one hundred feet. He elsewhere speaks of the injection of the masses of a similar ore near Arendal (*Ann. des Mines*, [4], xv, pp. 203, 204, 225). A careful study of his descriptions and plans will, however, we think, show that these great deposits of Scandinavia are, like the similar masses of ore in Canada and the United States, interstratified sedimentary layers. At the same time there exists in favor of the view maintained by Emmons, Rogers, Durocher, and other geologists, evidence similar to that adduced in favor of the eruptive origin of crystalline limestones; that is to say, the fact of veinstones consisting wholly or in part of magnetic oxyd of iron, An interesting example of this occurs near Dover, New Jersey, where large crystals of apatite occur in a gangue composed of triclinic feldspar and iron pyrites, imbedded in which latter occurs crystalline magnetite in rounded masses, sometimes half an inch in diameter, that were at first taken for ilmenite. Similar associations have been observed in other veins, and it is not improbable that the mixture of magnetite with a large proportion of zircon, described under the head of this species, may be from a veinstone. Another and an instructive instance is that described by Sir William Logan as occurring in the township of Ross, opposite Portage du Fort. Here a vein, or rather a group of reticulating veins and cracks, is seen in a white granular Laurentian limestone, cutting across the stratification, and sending off branches on either side in the plane of the limestone beds. These veins vary from a sixteenth of an inch to two or three inches in thickness, and are filled with highly crystalline magnetite, which in contact with the limestone presents in some parts large cubic and cubo-octahedral crystals. Two large veins, made up almost entirely of orthoclase and highly crystalline magnetite, each mineral often presenting cleavage planes of a square inch or more, have recently been met with in Buckingham, on the Ottowa. In these veins which intersect the gneiss, and have a breadth of nearly eighty feet each, the magnetite forms more than one-half the weight of the veinstone. Other and perhaps larger veins of magnetite may exist, and may have given countenance to the theory of its eruptive origin, but it is probable that few of the workable deposits of this ore are of the nature of veins. They appear to be conformable to the stratification, and are cut by the same veins which traverse the adjacent gneiss and limestone. Moreover, they are impregnated with the same minerals as the accompanying strata ; grains of apatite, scales of graphite, calcite, feldspar, pyroxene and garnet are occasionally found disseminated in the ore, which, by a predominance of some of these mixtures, passes into the accompanyiny gneiss, or into hornblendic or pyroxenic rock.

Hematite.—Among the Laurentian rocks of St. Lawrence and Jefferson counties, New York, several localities of crystallized red hematite, or specular iron, with brown spar and dodecahedral quartz, are met with, according to Beck, in small veins. In like manner, in the township of Bristol, on the Lac des Chats, specular iron, in broad crystalline plates, occurs with quartz, and also with calcite, in what appear to be true veins cutting the crystalline limestone and the adjoining gneiss. The octahedral peroxyd of iron, martite, which I described several years since as occurring with green hornblende, orthoclase and quartz, from Munroe, New York, is probably from a veinstone (*Amer. Jour. Science* [2], xiii, 372).

The workable deposits of the granular and compact varieties of hematite, which constitute the red iron ores of Northern New York and of Canada, appear, however, to be in all cases of the nature of beds, and the remarks with regard to the relation of the magnetic ores to the stratification are equally applicable to the present species. Although the great deposits of iron ores in the Laurentian rocks are chiefly of the magnetic species, beds of red hematite have been described as occurring in MacNab, on Iron Island, in Lake Nipissing, and elsewhere. In the Laurentian region of northern New York, in like manner the magnetic oxyd is the prevailing ore, especially in the eastern portion, while in St. Lawrence county the red hematite predominates, and forms very extensive deposits. In Beverley and in Bastard, Ontario, small beds of this ore occur in the Potsdam sandstone, which there rests directly on the Laurentian, and some of the other deposits of red hematite, already alluded to, may perhaps be found to rest upon this ancient system instead of forming part of it.

The magnetic and hematitic iron ores are sometimes intimately associated both in Scandinavia and in Canada. A specimen now before me from the great magnetic ore bed in Hull, Quebec, consists of two parallel layers, each about an inch thick, the one of coarsely granular magnetite, and the other of compact red hematite, not at all magnetic, the two being somewhat intermingled for half an inch at the junction. Grains of greenish feldspar are disseminated in the magnetite, and both it and the hematite contain imbedded crystalline plates of graphite a tenth of an inch or more in diameter. A film of scaly graphite, moreover, coats the free surface of the hematite layer.

Franklinite, Zincite.—The two remarkable ores, which are found together in Sterling and Franklin, New Jersey, were long since described by Prof. H. D. Rogers as occurring in veins which traverse the crystalline limestone of the region (*Final Report, Geol. N. Jersey*, 1840, pages 63, 64 and 69–71). The red oxyd or zincite sometimes forms the gangue of the franklinite; at other times the two ores are associated in a matrix of calcite, whose peculiar composition has already been noticed under its proper head. The silicate of zinc, willemite, is also occasionally found with the franklinite in the calcareous veinstone. It remains to be seen whether these ores do not, like the magnetite, occur in the stratified rocks of the region. These zinciferous minerals appear to be confined to a small area in New Jersey, as they have never yet been seen elsewhere in the Laurentian rocks of North America or of Scandinavia. They are sometimes accompanied by colorless transparent blende.

Iron Pyrites.—Cubic iron pyrites is of not unfrequent occurrence in the calcareous Laurentian veins, sometimes in distinct crystals, imbedded in calcite, and at other times filling up considerable portions of the veins, as in some localities in Burgess, and associated with apatite, pyroxene or mica. In an instance mentioned above, a massive pyrites is the gangue both of crystals of apatite and of magnetite. The pyrites from veins in the Laurentian rocks occasionally contains cobalt and nickel, sometimes in large proportions. A bronze colored, compact, impalpable variety, found in irregular reniform or globular masses, with copper pyrites, in North Burgess, gave me on analysis 3.47 per cent of cobalt and 2.21 per cent of nickel. It contained no arsenic.

It would seem scarcely necessary to mention the existence, in the strata, of a mineral so generally diffused as pyrites, were it not for two reasons: first, to recall that pyrites is sometimes disseminated in the beds of magnetic oxyd, so as to render the roasting of these, to remove the sulphur, a necessary preliminary to the smelting process; and second, to remark that the bands in the Laurentian gneiss are sometimes impregnated with pyrites to such an extent that their weathered surfaces become stained of a reddish hue from its decomposition. These iron-stained strata constitute what the German miners call *fahlbands*, and are often of economic interest, from containing ores of more precious metals, such as copper, zinc, cobalt, nickel or even gold and silver, either impregnating certain layers, or accumulated in veins, which intersect the fahlband. From a certain similarity in their chemical relations between all these metals, it happens that their sulphurets are very commonly associated in nature, so that a deposit of pyrites is not unfrequently impregnated with or accompanied by the sulphurets of more valuable metals.

MAGNETIC PYRITES is occasionally found in the Laurentian veins under conditions similar to those just mentioned for cubic pyrites. Near Portneuf, Quebec, a veinstone of calcite encloses small crystals of green pyroxene, together with considerable masses and imperfect crystals of magnetic pyrites.

COPPER PYRITES.—This ore is occasionally found with the Laurentian limestones both in Canada and in New York (*Geol. Can.*, page 692). In some cases it occurs in small irregular veins, with calcite, and occasionally with iron pyrites rich in cobalt and nickel, but unaccompanied by the minerals which generally characterize the Laurentian veinstones. In Escott, Ontario, however, it is found in considerable quantity, in a true granitic veinstone, with orthoclase, quartz, black tourmaline and mica. In the same township there was wrought a deposit of this ore, having apparently the form of a small lenticular bed, in immediate contact with a bed of magnetic iron ore (*Ibid*, page 693). Small veins filled with cubic and magnetic iron pyrites, copper pyrites and blende, with a little calcite, are found traversing a magnesian limestone in Madoc.

[In another locality in the same township similar veins, having a gangue of mixed calcite, bitter-spar and quartz, carry besides copper pyrites, galena and the two species of iron pyrites just mentioned, mispickel and argentiferous *fahlerz*, the latter species predominating and being associated with a little gold. The *mispickel* of the locality just described contains a trace of cobalt. The same mineral is found in several other localities in that vicinity, which moreover affords *sulphuret of antimony* in small quantities disseminated in dolomite, and in one instance associated with tremolite.]

[BISMUTHINE.—The sulphuret of bismuth is found in crystalline masses of considerable size in a vein cutting a plumbaginous limestone in Lake, in the province of Ontario. It is imbedded in quartz, and immediately associated with plumbago and brown tourmaline, delicate prisms of which are occasionally found penetrating the bismuthine. Minute portions of native bismuth are occasionally met with in the vein, and carbonate of bismuth, probably from the decomposition of the sulphuret, occurs near the surface. This vein belongs to the third class, already described, and in some parts by an admixture of mica and calcite passes into an aggregate which might be mistaken for a coarsely crystalline limestone. These calcareous portions of the vein are pinkish in color, with yellow phlogopite, and contain crystalline masses of iron pyrites.]

SULPHURET OF MOLYBDENUM.—This species, as mentioned in the *Geology of Canada*, pages 503 and 754, occurs in several localities in the Laurentian rocks. In the vicinity of Balsam Lake it is found in small quantities, associated with scapolite, pyroxene and iron pyrites, in a huge vein of quartz which traverses the crystalline limestones of that region.

[GOLD.—The occurrence of native gold has already been mentioned on page 66. Small portions of the precious metal have also been detected in assays of pyritiferous quartz from Belmont, and it is said in quartz from other localities, and also associated with beds of silicious rock impregnated with plumbago from more than one locality.]

GRAPHITE OR PLUMBAGO.—This mineral is occasionally met with in most of the stratified rocks of the Laurentian system; not only the limestones, but the gneiss, pyroxenite, quartzite and pyrallolite beds sometimes hold disseminated graphite. It is moreover met with in the iron ores of the series, as in Hull, Quebec, where large scales of graphite are imbedded in the crystalline magnetite, and also in Franklin, New Jersey, where, according to Dr. Fowler, the graphite disseminated in the magnetic iron ore is an obstacle to the working of it in the forge (*Rogers*, *Final Rep. Geol. New Jersey*, page 64). Beck has also described, as occuring near the Natural Bridge, in Lewis county, New York, a mixture of chlorite, graphite and red iron ore, the latter amounting to about one-half of the mass (*Mineralogy of New York*, page 26). The presence of graphite in the hematite which is associated with magnetite in Hull, has already been noticed above. It is, however, chiefly in the limestones that we find graphite disseminated, sometimes so finely divided as to give a bluish-grey tint to certain bands marking the stratification, and at other times appearing in thin detached films or flakes, also marking the stratification. Portions of the rock in this way sometimes become highly charged with graphite, and may form workable beds, but it is doubtful whether accumulations of pure crystalline graphite ever occur in the stratification.

Specimens of an impure amorphous graphite have lately been brought from Clarendon, Ontario, where it is said to form a bed of fifteen inches in thickness, in a fine grained mica-slate. The mineral is sub-conchoidal in fracture, earthy, bluish-black in color, dull, but assuming the lustre of graphite under the burnisher. It loses by ignition only 0.4 of volatile matter; by a prolonged calcination in the open air, however, the graphite is burned away, leaving 66.16 per cent of brownish-yellow residue, which yields to acids a little lime, magnesia and oxyd of iron, and then consists chiefly of a silicate in large part aluminous. This anhydrous argillaceous rock thus contains very nearly one-third its weight of amorphous or uncrystalline graphite.

Crystalline graphite is one of the most frequent minerals of the Laurentian veins, in which it occurs under a variety of aspects, sometimes as large plates, or hexagonal tables, disseminated in coarse-grained calcite, vitreous quartz, orthoclase or pyroxene, in scales between the laminæ of mica crystals, or else forming solid masses in the vein. These masses, when pure, are generally made of broad and thick laminæ, the edges of which, in some cases at least, are at right angles to the sides of the vein. In some cases a large vein will carry two or more bands or layers of pure or nearly pure graphite, separated from each other and from the wall-rock by feldspar, pyroxene or quartz. Occasionally the graphite found in these veins is finely granular, or like that from Warrensburgh, New York, breaks easily into rectangular masses, which exhibit on certain of the fractured surfaces a peculiar finely waved aspect, due to a structure which may be described as consisting of layers of a millimeter or less in thickness, tolerably regular, and made up of minute and narrow lamellæ, arranged at right angles to the layers, and presenting a fibrous or columnar aspect when broken across. When the fracture is with the layers, and thus exposes only the ends of the lamellæ, a granular surface is presented. Fractures at right angles with the layers show an undulating surface, recalling that of certain waved maple woods, and due to the fact that the fibres of the successive layers are not quite parallel with each other. This Laurentian graphite, according to Prof. C. F. Chandler's analysis, consists of carbon, 64.06; carbonate of lime, 32.90; the remaining three per cent being chiefly silica and oxyd of iron. The carbonate of lime is invisibly diffused through the mass, which effervesces freely with acids. It is not in any way connected with the peculiar waved structure, since the graphite from the famous mine of Marinski, in the Government of Irkutsk in Siberia, which presents a structure precisely similar, contains no carbonate of lime, and only small quantities of earthy impurities, amounting, according to Dumas, to 3.7 per cent of the purest specimens.

The Laurentian graphites, then, besides their visibly present foreign minerals, may contain finely disseminated impurities, which detract from their economical value, and can only be detected by analysis.

A Laurentian graphite from Patterson, New Jersey, crystallized in broad lamellæ, gave to Prof. Chandler, 21.0 per cent of pyrites, finely disseminated between the laminæ. This graphite, which by exposure becomes covered with an efflorescence of sulphate of iron, gave also portions of silica, alumina and lime, apparently derived from some mineral like scapolite, disseminated through the mass, and also enclosed small but distinct brown prisms of apatite.

On the other hand, a graphite from the third lot of the second range of Grenville, Quebec, closely resembling the last in appearance, was found to be of great purity. By long continued ignition it burned away, leaving only 1.27 per cent of foreign matter, which consisted of small, colorless, brilliant grains, apparently of quartz or feldspar, with a minute quantity of fawn-colored flocculi.

Portions of the specimens of graphite sent from Canada to the Exhibition at London in 1862, were furnished to Mr. Regnault, the eminent French chemist and physicist, who has since made use of them in an investigation on the specific heat of this form of carbon. Incidental to this inquiry, they were submitted to a careful analysis by Mr. Cloez; after being calcined to expel any traces of moisture, they were burned in a current of dry oxygen and showed the fact, already suspected by Regnault, that a portion of hydrogen enters into their composition, and is only separated by prolonged ignition in a current of dry chlorine, which at the same time separates the earthy impurities, in the form of chlorids, and leaves the graphite an almost chemically pure carbon. The analysis of a specimen, probably from the same locality with that which gave me 1.27 per cent of ash, gave to Cloez, carbon, 98.56; hydrogen, 1.34; ash, 0.20 = 100.10. Two other specimens of Canadian graphite gave him, respectively, 12.60 and 23.40 per cent of argillaceous ash (*Ann. de Chim. et de Phys.* [4], vii, 450).

The lamellar graphite above noticed, like that of most of the similar graphites known in Grenville and the adjacent region, occurs in veins traversing the crystalline limestones, which are themselves more or less impregnated with graphite. In other cases, however, the wall-rock is gneiss, as in Ticonderoga, New York, where, in addition to the graphite veins, interstratified layers highly charged with lamellar crystalline graphite are extensively mined in the Laurentian gneiss. A small vein, also in gneiss, occurs near Mud Lake, in Loughborough, Ontario. The graphite of the Laurentain veins is similar in its characters to the crystalline graphites of Ceylon, the mineralogical resemblances of whose rocks to the Laurentian series we have already pointed out. These graphites are distinguished by their highly crystalline texture, their metallic gray streak and lustre, and their comparative freedom from ordinary earthy impurities, although, as we have seen, they may include admixtures of carbonate of lime and sulphuret of iron.

There is, however, another class of graphites belonging to the stratification, and evidently of sedimentary origin, containing a large admixture of earthy materials, such as sand and clay. These graphites are generally amorphous, or but imperfectly crystalline, and ordinarily give a much darker streak than the purer varieties. To this second class belongs the earthy graphite from Clarendon, Ontario, already described, and that of many other localities, where the mineral has been formed by the alteration of more or less carbonaceous layers in schistose rocks. The impure plumbaginous schists from the Quebec group of the Eastern Townships of the province of Quebec ; the beds of graphite in the micaceous schists of eastern Massachusetts, at Sturbridge, Worcester and elsewhere, which are now recognized to be altered beds of coal ; those of the French Alps, which are associated with fossil plants, and those of Passau, in Bavaria, where the mineral is disseminated in gneiss of Laurentian age, are also examples of this second class of graphites. To these we may add the graphite of Borrowdale, in Cumberland, which is found in lenticular masses in altered slates, and the beds of graphite in mica-slate, in New Hampshire, which in some cases passes into a plumbaginous mica-slate, holding garnets. In describing the latter deposits, Dr. Jackson has observed that in the town of Goshen the beds of graphite are intersected with cross veins, which are filled with pure foliated graphite.

These graphites of the second class are distinguished not only by the large proportion of silicious and argillaceous matters with which they are mingled, but also by the very general absence of crystalline texture. This is so evident a characteristic, that Sir Benjamin Brodie, in his recent researches on the chemical relations of graphite, distinguishes two varieties—the amorphous, including that from Borrowdale and from Passau, and the lamellar or crystalline, represented by the graphite associated with quartz from Ceylon, and that from Ticonderoga, New York (*Philos. Transactions* 1859, page 249), the latter of which belongs to Laurentain veins. The graphites from New Brunswick and from Greenland, according to him, approach to anthracite in character, and probably, like that of Massachusetts, pass into this variety of mineral carbon (*Lyell. Geol. Journal*, I, 199.—*Hitchcock's Geol. Mass.*, page 127). Between the amorphous graphite of Brodie, represented by that of Borrowdale and Passau, and the lamellar variety from Ceylon and from the Laurentian veins of North America, may be placed the interstratified graphites of New Hampshire and of Sturbridge, Massachusetts, which are more or less crystalline in texture. It will probably be found that the highly crystalline lamellar graphite belongs, in all cases, to true veins, where a slow process of deposit has allowed it to assume that mode of aggregation and that purity which characterize other minerals thus deposited.

The presence of graphite in veins under such conditions and associations as have already been described, implies its separation from solution at an elevated temperature, and in this connection the curious researches of Brodie, above referred to, have shown that this form of carbon is possessed of singular chemical properties and affinities, which, when farther studied, may serve to explain its solution and crystallization. Meanwhile, the observations of Pauli have established that when hydrate of soda, mixed with cyanid of sodium, is heated with nitrate of soda to incipient redness, the carbon of the cyanid separates from the liquid mass in the form of graphite. Pauli moreover suggests that native graphite may have been separated from certain carbon compounds by a process analogous to this (*Philos. Mag.*, [4], xxi, 541). The direct transformation into graphite of carbonaceous matter cannot, however, be doubted by geologists, and such a hypothesis is therefore untenable for the stratified graphites. This reaction described by Pauli is nevertheless instructive, as showing that graphite may be separated from solutions at a temperature not higher than that at which, according to Sorby, the minerals which accompany it in the Laurentian veins have crystallized, although we cannot, in the formation of these veins, suppose the intervention of these same chemical reagents as in the experiment of Pauli.

Graphite may undoubtedly be formed at much higher temperatures. Its occurrence in cast-iron is well known; and Brodie, who obtained, by dissolving a graphitic iron in acid, four per cent of lamellar graphite, found it to be identical in physical characters with that met with in nature. Jacquelain also, by the decomposition of sulphuret of carbon in contact with metallic copper, at 800° Centigrade, obtained, together with sulphuret of copper, amorphous graphite. Starting from this experiment, Jacquelain suggests that native graphite may have originated from the distillation into the fissures of rocks of volatile hydro-carbons, which have there, by a decomposition similar to that which takes place in contact with the walls of coal-gas retorts, given rise to a deposit of carbon that has assumed the form of graphite (*Cosmos*, June 23, 1864). This hypothesis, evidently inadmissible for the graphite found as a disseminated mineral in stratified rocks, is not less so for that found in veins, where its associates are minerals whose presence is incompatible with the high temperature supposed. Graphite, when ignited with carbonate of lime, gives rise to carbonic oxyd, and under similar conditions reduces iron from its oxyd to the metallic state. It even decomposes the vapor of water at a red heat. We are hence led to regard the graphite of bedded rocks as having been formed by the alteration of coal and similar carbonaceous matters at a temperature below redness, while its subsequent translation into the veins, and its deposition in a crystalline form, together with various other minerals, as it occurs in the Laurentian veins, have been effected under conditions which, although imperfectly understood, probably included aqueous solution, and a temperature not far below a red heat.

[ANTHRACITE.—Under this name, for want of a better term, may be described the black carbonaceous matter which has already been noticed as associated with native gold, bitter-spar and a reddish ochre, derived from the decomposition of the latter, at the Richardson mine in Madoc, Ontario. The anthracite seems like the similar material associated with quartz crystals in Herkimer county, New York, to have been deposited contemporaneously with the quartz and bitter-spar, in some cases lining the walls of the vein, and in others appearing in masses an inch or more in diameter in the middle of the veinstone. It is jet black in color, with a conchoidal fracture and a somewhat resinous lustre, and is soft and easily crushed between the fingers.

When exposed to heat in a tube it give out some water, but no bituminous matter; in the open air at a red heat, it takes fire and burns readily without flame, leaving a somewhat abundant ash, whitish and sometimes reddish, consisting of carbonate of lime with some silicious and ferruginous matter, including a quantity of gold. This metal is visible in the form of grains and scales in the recent fractures of the black substance, which, although coal-like in its aspect, resembles more the carbonaceous matter which has been described in the *Geology of Canada* as filling veins or fissures in the rocks of the Quebec group, and is doubtless derived from the transformation of bitumen. This substance, as I have shewn, is in some cases so far altered by oxydation as to have a composition like that of anthracite, and is then scarcely distinguishable from the Madoc mineral.

The gold, as already stated, occurs both in fine scales, disseminated through the black anthracitic matter, and in large crystalline grains and plates, imbedded in the bitter-spar, sometimes associated with quartz, black hornblende and iron pyrites. From this it would appear that the introduction of the gold was not only contemporaneous with the deposition of the bitter-spar, but continued after the introduction of bitumen.

Carbonaceous matters not unfrequently occur in mineral veins in other regions, and are met with in several localities in the Laurentian rocks of Scandinavia, where, according to Daubrée, in the silver mine of Kongsberg, a matter allied to anthracite and similar to that of Madoc, occurs in mammillary masses imbedded in the calc-spar of the veinstone, and sometimes penetrated by native silver (*Ann. des Mines* [4], iv, p. 260). In other veins in that region the presence of bitumen is indicated, and in the beds of magnetic iron ore, found in gneiss at Dannemora, small masses of a matter closely resembling bituminous coal in composition, and penetrated by quartz veins, occur in the midst of the ore. See in this connection Igelstrom's recent observations on the bituminous gneiss of Wermland, in Sweden (*Amer. Jour. Science*, [2], xlv, 38). According to Daubrée, both graphite and anthracite, where they occur in the ancient rocks of Scandinavia, are accompanied by bitumen. No such associations have hitherto been observed with the graphite of our Laurentian series.

The above details are chiefly taken from the *Report on the Gold of the County of Hastings*, already cited.]

P. S.—More recent researches by the Geological Survey of Canada, have shown that the rocks of Hastings county, Ontario, noticed on page 48, rest unconformably upon the Laurentian, and belong to one and possibly two distinct systems. The upper and larger portion consists in great part of mica-schists and micaceous limestones, while at the base are great masses of dioritic and hornblendic schists with iron ore, possibly of Huronian age. To the basal portion of this upper series belong the steatite, page 79; as also the gold, page 66; the bismuth ores of page 91, and the anthracite of page 97. The upper works of Hastings are noticed by me in the *American Journal of Science*, for July, 1870, page 85.
T. S. H.

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